

SATURN S-IVB-207 STAGE ACCEPTANCE FIRING REPORT

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ABSTRACT

This report presents an evaluation of the Saturn S-IVB-207 stage acceptance firing that was conducted at the Sacramento Test Center on 19 October 1966. Included in this report are stage and ground support equipment deviations associated with the acceptance firing configuration.

The acceptance firing test program was conducted under National Aeronautics and Space Administration Contract NAS7-101, and established the acceptance criteria for buy-off of the stage.

DESCRIPTORS

Saturn S-IVB-207 Stage	Saturn S-IVB-207 Acceptance Firing
Saturn S-IVB/IB Stage	Saturn S-IVB-207 Stage Test Configuration
J-2 Engine	Sacramento Test Center
Complex Beta	Sequence of Events
Countdown Operations	

PREFACE

The purpose of this report is to document the evaluation of the Saturn S-IVB-207 stage acceptance firing as performed by Douglas personnel at the Sacramento Test Center.

This report, prepared under National Aeronautics and Space Administration Contract NAS7-101, is issued in accordance with the contractual requirements of Douglas Report No. SM-41410, Data Submittal Document, Saturn S-IVB System, dated 1 December 1965.

This report evaluates stage test objectives, instrumentation, and configuration deviations of the stage, test facility, and ground support equipment.

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SECTION 1

INTRODUCTION

1. INTRODUCTION

1.1 General

This report was prepared at the Douglas Huntington Beach Space Systems Center by the Saturn S-IVB Test Planning and Evaluation (TP&E) Committee for the National Aeronautics and Space Administration under Contract NAS7-101.

Activities connected with the Saturn S-IVB-207 stage included prefiring checkout and the acceptance firing. Checkout started at the subsystem level and progressed to completion with the integrated systems test and the simulated static firing. The information contained in the following sections documents and evaluates all events and test results of the acceptance firing which was completed on 19 October 1966. The tests were performed at the Complex Beta, Test Stand I, Sacramento Test Center (STC).

1.2 Background

The S-IVB-207 stage was assembled at the Huntington Beach Space Systems Center. A checkout was performed in the vertical checkout laboratory (VCL) prior to shipping the stage to STC. The stage was delivered to STC on 31 August 1966 and installed on test stand I on 1 September 1966. The stage was ready for acceptance firing on 17 October 1966.

The APS modules were shipped to the manufacturing and assembly (M&A) building at STC for leak and functional checks. No confidence firings of these modules were scheduled.

Table 1-1 lists the milestones of the Saturn S-IVB-207 stage events and dates of completion.

1.3 Objectives

All test objectives outlined in Douglas Report No. SM-47457A, Saturn S-IVB-207 Stage Acceptance Firing Test Plan, dated July 1966 and revised September 1966 were successfully completed.

Stage acceptance objectives which provided maximum system performance evaluation were as follows:

- a. Countdown control and operation capability verification
- b. J-2 engine system performance verification
- c. Oxidizer system performance verification
- d. Fuel system performance verification
- e. Pneumatic control system performance verification
- f. Propellant utilization system performance verification
- g. Stage data acquisition system performance verification
- h. Stage electrical control and power system performance verification
- i. Hydraulic system and J-2 engine gimbal control performance verification
- j. Structural integrity verification
- k. APS stage interface compatibility verification.

TABLE 1-1
MILESTONES, SATURN S-IVB-207 STAGE

EVENT	COMPLETION DATE
Tank Assembly	8 January 1966
Proof Test	14 January 1966
Insulation and Bonding	11 March 1966
Stage Checkout and Join J-2 Engine	13 May 1966
Systems Checkout	9 July 1966
Ship to STC	31 August 1966
Stage Installed on Test Stand	1 September 1966
Ready for Acceptance Firing	17 October 1966
Acceptance Firing	19 October 1966
Stage Received at VCL	3 November 1966
All Systems Test	18 November 1966
Ready for Storage	23 November 1966
Ready for Delivery (Signed D0250)	30 November 1966

SECTION 2

SUMMARY

2. SUMMARY

The S-IVB-207 stage was acceptance fired on 19 October 1966 at Complex Beta, Test Stand I, Sacramento Test Center. The countdown was designated as CD 614074. The mainstage firing duration was 445.6 sec; engine cutoff was initiated through the PU processor when LOX was depleted below the 1 percent level.

2.1 Countdown Operations

Countdown 614074 was initiated on 18 October 1966 and proceeded smoothly to a successful acceptance firing on 19 October 1966.

The following anomalies were experienced during the countdown:

- a. A severe leak appeared in the LOX sled main fill valve at the initiation of loading. The valve was left open for the duration of the countdown with main LOX flow being controlled through the facility transfer line valve.
- b. The No. 1 LH2 depletion sensor cycled several times during LH2 loading but at 92 percent load, stabilized and appeared to operate properly throughout the remainder of the countdown.
- c. Approximately 5 minutes after completion of LH2 loading, the auxiliary hydraulic pump cycled on for 12.5 min. This had not been experienced during past acceptance firings; however, it was expected if temperatures were sufficiently low.

2.2 J-2 Engine System

The J-2 engine (S/N 2056) performed satisfactorily throughout the acceptance firing. Engine flight modifications (pre-fire and post-fire) were made at STC (section 6).

2.3 Oxidizer System

The oxidizer system functioned properly, supplying LOX to the engine LOX pump inlet within the specified operating limits. Ullage pressure was maintained at a level adequate to insure engine pump net positive suction pressures above the minimum required to prevent pump cavitation.

2.4 Fuel System

The fuel system performed as designed and supplied LH2 to the engine LH2 pump inlet within the limits defined in the engine specification.

During the LH2 turbopump chillover, the LH2 pump inlet temperature was indicating 2 to 3 deg higher than expected. Investigation of possible sources of heat input has not produced any results. A suspected area is the chillover shutoff valve insulation. Additional checks could not be performed at this time because the insulation has been removed for valve replacement.

2.5 Pneumatic Control and Purge System

The pneumatic control and purge system performed satisfactorily throughout the acceptance firing. The helium supply to the system was adequate for both pneumatic valve control and purging; the regulated pressure was maintained within acceptable limits and all components functioned normally.

2.6 Propellant Utilization (PU) System

The PU system accomplished all the design objectives as listed in DAC Report No. SM-47457A, Saturn S-IVB-207 Stage Acceptance Firing Test Plan.

2.7 Data Acquisition System

The data acquisition system performed satisfactorily throughout the acceptance firing. One hundred and seventy-two measurements were active of which 3 failed resulting in a measurement efficiency of 98.3 percent.

2.8 Electrical Power and Control Systems

The electrical power and control systems performed satisfactorily throughout the acceptance firing. All firing objectives were satisfied and all system variables operated within design limits.

2.9 Hydraulic System

The hydraulic system operated properly supplying pressurized fluid to the servo-actuators. All specified test objectives were achieved and all system variables operated within design limits.

2.10 Flight Control System

The dynamic response of the hydraulic servo-thrust vector control system was measured while the J-2 engine was gimbaled during the acceptance firing. The performance of the pitch and yaw hydraulic servo control systems was found to be acceptable.

2.11 Structural System

Structural integrity of the stage was maintained for the vibration, temperature, and thrust load conditions of the acceptance firing. A post acceptance firing inspection of the stage revealed no debonding or other discrepancies resulting from the cryogenic loading and firing. A visual inspection of the LH2 tank interior was made from the manhole; no discrepancies were noted.

2.12 Thermoconditioning and Purge System

The thermoconditioning and purge system functioned properly during the acceptance firing. All system temperatures and flowrates were maintained within design limits.

2.13 Reliability and Human Engineering

All functional failures of Flight Critical Items and Ground Support Equipment/Special Attention Items were investigated by Reliability Engineering. A Human Engineering evaluation was conducted in support of the acceptance firing and no significant man-machine problems were identified.

3. TEST CONFIGURATION

This section describes the stage and ground support equipment (GSE) deviations and modifications from the flight configuration affecting the acceptance firing. Additional details of specific system modifications are discussed in appropriate sections of this report. The S-IVB-207 stage configurations are described in Douglas Drawing No. 1B66532, S-IVB/IB Stage End Item Test Plan.

Figure 3-1 is a schematic of the S-IVB-207 stage propulsion system and shows the telemetry instrumentation transducer locations from which the test data were obtained. The functional components are listed in table 3-1. Hardwire measurements are noted on the appropriate subsystem schematics included in this report. The propulsion system orifice characteristics and pressure switch settings are presented in tables 3-2 and 3-3. Engine S/N J-2056 was installed.

The propulsion GSE (figure 3-2) consisted of pneumatic consoles "A" and "B", two propellant fill and replenishing control sleds, a vacuum system console, and a gas heat exchanger.

3.1 Configuration Deviations

Configuration deviations required for the acceptance firing are discussed in DAC Report No. SM-47457A, Saturn S-IVB-207 Stage Acceptance Firing Test Plan. Significant configuration changes to the stage and GSE are discussed in the following paragraphs.

3.1.1 Engine Restrainers

J-2 engine unlatch restrainer link kit, Model DSV-4B-618, was installed to restrain the engine during start transient side loads.

3.1.2 Quick Disconnects

The stage-mounted portions of the pneumatic and propellant umbilical quick-disconnects were replaced with hardlines.

3.1.3 Engine Diffuser

A water-cooled converging diffuser, Model DSV-4B-639 engine bell extension service unit, was installed to the engine thrust chamber exit to reduce the nozzle area ratio and the probability of jet-separation-induced side loads.

3.1.4 Auxiliary Pressurization

An auxiliary propellant tank pressurization system was installed and was supplied from a GSE ambient helium source.

3.1.5 Propellant Fast Fill Sensors

Propellant loading fast fill sensors were installed on the instrumentation probes but were used in the indicating mode only.

3.1.6 Stage Vent and Bleed System

All stage propellant vent and bleed systems were connected to the facility vent system.

3.1.7 Forward Skirt Cooling

The forward skirt thermoconditioning system coolant was supplied by a Model DSV-4B-359 servicer, rather than the flight source in the instrument unit.

3.1.8 Aft Interstage

The stage was mounted on a Model DSV-4B-540 dummy aft interstage instead of the flight interstage.

3.1.9 Fire Detection System

A resistance wire fire detection system was installed for monitoring critical areas of the stage, GSE, and facilities.

3.1.10 GH2 Detectors

A GH2 leak detection system was installed for monitoring critical areas of the stage, GSE, and facilities.

3.1.11 Blast Detectors

Blast detectors were installed in the test area to monitor ranges of 0 to 25 psi overpressure.

3.1.12 Auxiliary Propulsion System (APS)

The flight APS modules were not installed. Instead, the Model 188B APS Simulators were connected to APS positions 1 and 2 to receive commands and close the control circuitry.

3.1.13 Telemetry System

Those telemetry channels that were left blank when various parameters were disconnected to be recorded by other means were either left as open channels or were simulated.

3.1.14 Hardwire Transducers

The Marshall Space Flight Center static firing measurement (Scope Change 1195A) program hardwire transducers were installed for the acceptance firing. These measurements will be removed before the stage leaves STC.

3.1.15 Forward Stage/Instrumentation Unit (IU) Interface

The IU was not available at the Sacramento Test Center; therefore, the IU and S-IB electrical interfaces were simulated by GSE.

3.1.16 Electrical Umbilicals

The electrical umbilicals remained connected throughout the acceptance firing.

3.1.17 Instrumentation System

The stage data acquisition system was as defined in Douglas Drawing No. 1B43560, Instrumentation Program and Components List, Saturn S-IVB-207, except as called out in section 12.

3.1.18 Electrical Power System

The Model DSV-4B-170 battery power unit was used during the acceptance firing when stage systems were switched to internal power.

3.1.19 Propellant Utilization (PU) System

The S-IVB-206 stage PU system electronics package was used for the S-IVB-207 stage acceptance firing.

SECTION 3

TEST CONFIGURATION

TABLE 3-1 (Sheet 1 of 5)
S-IVB-207 STAGE HARDWARE LIST

ITEM NO.*	PART NO.	NAME
1	7851861-1	Disconnect, LH2 tank pressurization
2	1B65673-1	Valve, check, LH2 tank prepressurization line
3	1B53817-505	Valve, hand, 2-way, LH2 and LOX fill and drain valves, nonpropulsive vent and LH2 chilldown valve purge line
4	1B51361-1	Valve, check, LH2 fill and drain valve and nonpropulsive vent purge line
5	1B53817-505	Valve, hand, 3-way, LOX vent and relief valve purge line
6	7851823-503	Disconnect, ambient, helium fill
7	1B63206-1	Orifice, ambient helium fill
8	1B51361-1	Valve, check, control helium fill
9	1A57350-505	Module, control helium fill
10	1A49963-1	Sphere, control helium, 905 sci
11	1A48848-505	Disconnect, LH2 tank vent
12	1B66932-501	Disconnect, LH2 fill and drain
13	1B40622-505	Orifice, LH2 fill and drain valve purge line
14	1B65292-501	Module, actuation control, LH2 fill and drain valve
15	1B41065-1	Disconnect, common bulkhead vacuum system
16	1A48240-505	Valve, LH2 fill and drain
17	1B66932-501	Disconnect, LOX fill and drain
18	1B51361-1	Valve, check, LOX fill and drain valve purge line
19	1B40622-505	Orifice, LOX fill and drain valve purge line
20	1A48240-505	Valve, LOX fill and drain

* - Indicates location in figures 3-1 and 3-2.

P/U - Pickup

D/O - Dropout

TABLE 3-1 (Sheet 2 of 5)
S-IVB-207 STAGE HARDWARE LIST

ITEM NO.*	PART NO.	NAME
21	1B65292-501	Module, actuation control, LOX fill and drain valve
22	1A57781-501	Module, cold helium fill
23	1B40824-503	Valve, check, cold helium fill line
24	1B42290-503	Module, LOX tank pressure control
25	7851844-501	Disconnect, cold helium fill and LOX tank prepressurization
26	1B40824-503	Valve, check, cold helium fill and LOX prepressurization line
27	1A49991-1	Plenum, LOX tank pressurization, 250 sci
28	7851830-517	Switch, pressure, LOX tank pressurization regulator backup P/U 465 +20, -15 psia, D/O 350 +20, -15 psia
29	1B63047-509	Orifice, LOX tank pressurization, heat exchanger primary
30	1B63047-509	Orifice, LOX tank pressurization, heat exchanger bypass
31	1A49958-517	Disconnect, thrust chamber jacket purge and chilldown
32	1B51361-1	Valve, check, thrust chamber jacket purge line
33	1B43657-11	Module, pneumatic power control
34	1A48857-1	Plenum, control helium, 100 sci
35	1B55200-505	Module, LH2 tank pressure control
36	1B51361-1	Valve, check, LH2 nonpropulsive vent purge line
37	1B40622-501	Orifice, LH2 nonpropulsive vent purge line
38	1B59265-1	Orifice, nonpropulsive vent
39	1B59265-1	Orifice, nonpropulsive vent
40	7851860-541	Switch, pressure, LH2 flight control, P/U 29.5 psia, D/O 26.5 psia

* - Indicates location in figures 3-1 and 3-2.

P/U - Pickup

D/O - Dropout

TABLE 3-1 (Sheet 3 of 5)
S-IVB-207 STAGE HARDWARE LIST

ITEM NO.*	PART NO.	NAME
41	7851860-537	Switch, pressure, LH2 prepressurization and ground fill, P/U 34 psia, D/O 31 psia, min
42	1A67005-507	Switch, pressure, LH2 tank orbital vent initiation, P/U 35.5 \pm 0.75 psia, D/O 31 psia, min
43	Deleted	
44	1B53817-1	Valve, 3-way, LH2 tank pressure switch shutoff
45	1A49988-1	Valve, directional control, LH2 vent
46	1A49591-527	Valve, relief, LH2 tank, crack 40 psia, max, reseal 37 psia, min
47	1A48257-509	Valve, vent and relief, LH2 tank, crack 39 psia, max, reseal 37 psia, min
48	1A48851-1	Sphere, storage, cold helium (6 each)
49	1B58100	Probe, LH2 temperature sensor
50	1A48431-501	Probe, LH2 mass sensor
51	1A69405	Probe, LOX temperature sensor
52	1A48430-507	Probe, LOX mass sensor
53	1A49421-501	Pump, LH2 chilldown
54	1A48854-1	Orifice, LOX chilldown pump purge line
55	1A58347-505	Module, LOX chilldown pump purge
56	1A49423-505	Pump, LOX chilldown
57	1A49964-501	Valve, check, LOX chilldown return line
58	7851847-535	Switch, pressure, LOX chilldown pump purge regulator backup P/U 53 psia, max D/O 49 psia, min

* - Indicates location in figures 3-1 and 3-2.

P/U - Pickup

D/O - Dropout

TABLE 3-1 (SH 4 of 5)
S-IVB-207 STAGE HARDWARE LIST

ITEM NO.*	PART NO.	NAME
59	114-109 (PESCO)	Valve, relief, LOX chilldown pump motor, container, crack and reseal 65 psia to 85 psia
60	1A67913-1	Valve, vent, LOX chilldown pump motor container
61	1A49965-521	Valve, shutoff, LOX chilldown line
62	1A89104-509	Flowmeter, LOX chilldown line
63	1A87749-1	Strainer, LOX chilldown pump discharge
64	1A49968-509	Prevalve, LOX
65	1B53817-505	Valve, 3-way, LOX tank pressure switch shutoff
66	Deleted	
67	1B65292-501	Module, actuation control, directional valve, LH2 vent
68	1B65292-501	Module, actuation control, LH2 vent and relief valve
69	7851847-533	Switch, LOX prepressurization, flight and ground fill control, P/U 40 psia, max, D/O 37 psia, min
70	1A49964-501	Valve, check, LH2 chilldown return line
71	1A49968-507	Prevalve, LH2
72	1A49965-519	Valve, shutoff, LH2 chilldown pump discharge
73	1B52985-501	Strainer, LH2 chilldown pump discharge
74	1B53920-503	Valve, check LH2 chilldown pump discharge
75	1A89104-507	Flowmeter, LH2 chilldown pump discharge
76	1B65292-501	Module, actuation control, prevalves and chilldown valves
77	1B40622-507	Orifice, LH2 chilldown shutoff valve purge line, 14 scfm

* - Indicates location in figures 3-1 and 3-2.

P/U - Pickup

D/O - Dropout

TABLE 3-1 (Sheet 5 of 5)
S-IVB-207 STAGE HARDWARE LIST

ITEM NO.*	PART NO.	NAME
78	1B51361-1	Valve, check, LOX vent and relief valve purge line
79	Deleted	
80	1B63206-1	Orifice, flow, LOX vent and relief valve purge line
81	1A49590-513	Valve, relief, LOX tank, crack 45 psia, reseal 42 psia
82	1A48312-505	Valve, vent and relief, LOX tank, crack 44 psia, reseal 41 psia
83	1B65292-501	Module, actuation control, LOX vent and relief valve
84	1B56804-1	Module, engine purge control
85	1A67002-509	Switch, pressure, engine purge regulator backup, P/U 130 psia, max, D/O 105 psia, min
86	1A49958-521	Disconnect, engine start sphere vent and relief valve drain
87	1A49958-515	Disconnect, engine control helium sphere fill
88	1A49958-523	Disconnect, engine start sphere fill

* - Indicates location in figures 3-1 and 3-2.

P/U - Pickup

D/O - Dropout

TABLE 3-2 (Sheet 1 of 3)
S-IVB-207 STAGE AND GSE ACCEPTANCE FIRING ORIFICES

ITEM* NO.	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (IN. ²)
	<u>Stage</u>			
7	Ambient helium fill	65 scfm	--	Sintered
13	LH2 fill and drain valve purge	15 scim at 3,200 psid	--	Sintered
19	LOX fill and drain valve purge	15 scim at 3,200 psid	--	Sintered
29	LOX tank pressurization system heat exchanger outlet	0.219 in. dia	0.88	0.0333
30	LOX tank pressurization system heat exchanger bypass	0.185 in. dia	0.85	0.0228
35	LH2 tank pressurization module			
	Undercontrol	0.252 in. dia	0.89	0.0445
	Overcontrol	0.228 in. dia	0.90	0.0808
	Step	0.323 in. dia	0.82**	0.1414**
37	LH2 tank nonpropulsive vent purge	1 scfm at 3,200 psid	--	Sintered
38-39	LH2 tank nonpropulsive vent (2)	2.180 in. dia	NC	--
54	LOX chilldown pump purge flow control	37 scim at 475 psid	--	Sintered
55	LOX chilldown pump purge module	0.00166 lbm/sec at 475 psig IN and 85 psig OUT	+	

*Indicates location in figures 3-1 and 3-2.

**Discharge coefficient and effective area are calculated for overcontrol and step orifices in successive combination with the undercontrol orifice.

+Not available.

TABLE 3-2 (Sheet 2 of 3)
S-IVB-207 STAGE AND GSE ACCEPTANCE FIRING ORIFICES

ITEM NO.	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (IN. ²)
77	LH2 chilldown valve purge	65 scfm at 3,000 psid	--	Sintered
80	LOX tank vent and relief valve purge	65 scfm at 3,000 psid	+	0.00043
84	Engine pump purge module	0.00166 lbm/sec at 475 psig IN and 85 psig OUT	--	0.00023
	<u>Console A</u>			
A9538	LH2 tank repressurization supply	Union	--	--
A9537	Pressure switch checkout -- high pressure	0.032 in. dia	--	--
A9536	Pressure switch checkout -- low pressure	1.2 scfm	--	Sintered
A9535	LH2 tank and umbilical purge supply	0.260 in. dia	0.88	0.04675
--	All console A stage bleeds	Variable	--	--
A9515	Pressure actuated valve and mainstage pressure switch supply	1.2 scfm	--	Sintered
A9533	LH2 system checkout supply	1.2 scfm	--	Sintered
A9534	LOX system checkout supply	5.0 scfm	--	Sintered
A9539	Console GN2 inerting supply	0.013 in. dia	--	--
A9526	J-box inerting supply	0.013 in. dia	--	--

+Not available.

TABLE 3-2 (Sheet 3 of 3)
S-IVB-207 STAGE AND GSE ACCEPTANCE FIRING ORIFICES

ITEM NO.	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (IN. ²)
	<u>Console B</u>			
--	All console B stage bleeds	Variable	--	--
A9529	LOX tank and umbilical purge system	0.305	--	--
--	Turbine start sphere supply	Union	--	--
A9552	Turbine start sphere supply vent	0.081 in. dia	0.93	0.00479
A9528	Thrust chamber jacket purge and chilldown system	0.072 in. dia	0.89	0.00362
9525	Engine control sphere supply	0.125 in. dia	0.84	0.00965
A9527	LH2 tank prepressurization supply	0.162 in. dia	0.80	0.01649
A9348	Console GN2 inerting supply	Manifold	--	--
A9540	J-box inerting supply	0.013 in. dia	--	--
A9550	Engine control sphere supply vent	--	--	--
--	LOX tank prepressurization supply	0.096 in. dia	0.94	0.00680

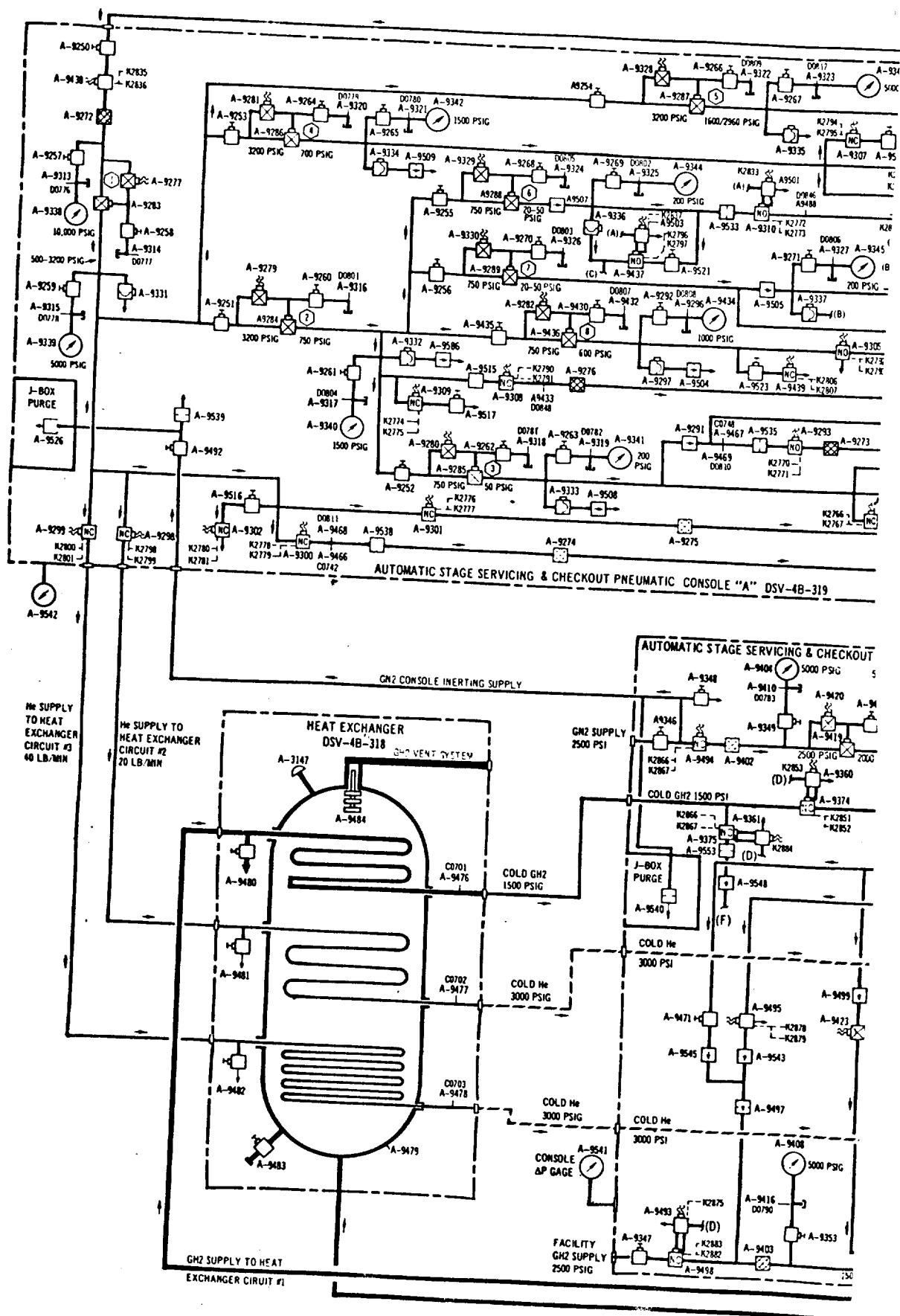
TABLE 3-3
S-IVB-207 STAGE PRESSURE SWITCHES

PARAMETER	PART NO.	PRESSURE (PSIA)					
		SPECIFIED		PRETEST		POST-TEST	
		PICKUP	DROPOUT	PICKUP	DROPOUT	PICKUP	DROPOUT
<u>LH2 TANK</u>							
Flight control	785186J-541	30.0 max	26.5 min	29.65	26.48	29.3	27.1
Prepressurization and ground fill valve control	7851860-537	34.5	30.5	33.93	30.56	34.33	31.10
Orbital vent	7851860-543	35.25 ^{+0.75} -1.25	30.5	35.68	31.54	35.3	32.2
<u>LOX TANK PRESSURIZATION SYSTEM</u>							
LOX prepress, flight control and ground fill valve control	7851847-533	41 max	36.5 min	40.62	38.03	40.53	37.91
LOX tank regulator backup	7851830-517	444-491	329.376	451.8	342.8	450.5	343.0
<u>PNEUMATIC CONTROL SYSTEM</u>							
Power control module	7851830-521	600 ⁺²¹	490 ⁺³¹	611.4	503.0	609.8	503.6
LOX chill pump motor container	7851847-535	54.5 max	48.5 min	52.5	49.9	NO CHECK	
Engine pump purge	1A67002-509	136 max	99 min	120.7	111.0	NO CHECK	
<u>J-2 ENGINE</u>							
Mainstage OK No. 1	PS-5874A500	515 ⁺³⁰	P/U minus 62.5 ^{+37.5}	517.90	443.91	522.01	444.32
Mainstage OK No. 2	PS-5874A500	515 ⁺³⁰	P/U minus 62.5 ^{+37.5}	515.41	443.29	516.08	444.82

NOTE: All pressures listed are the average of three actuations.

SECTION 4

COUNTDOWN OPERATIONS



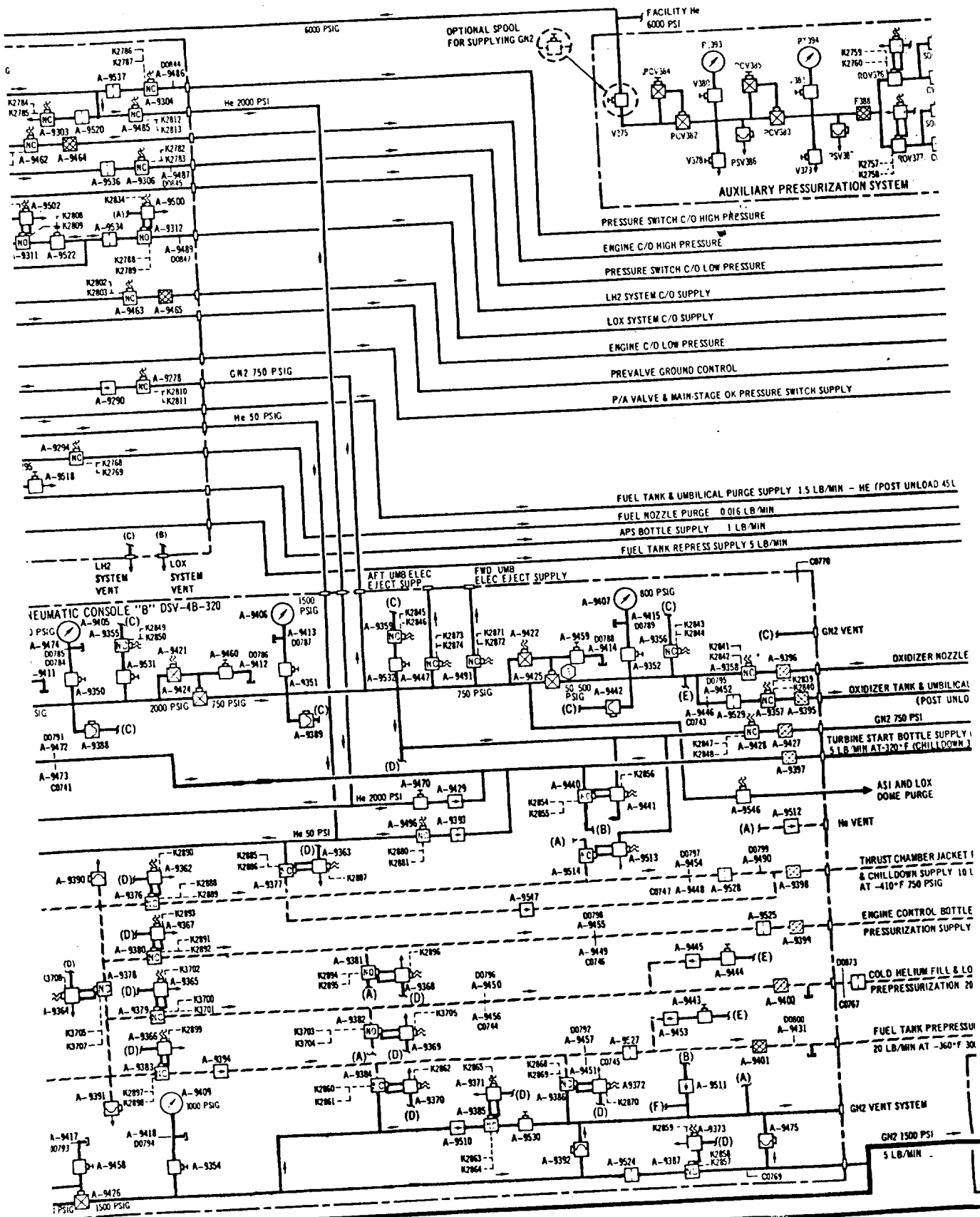
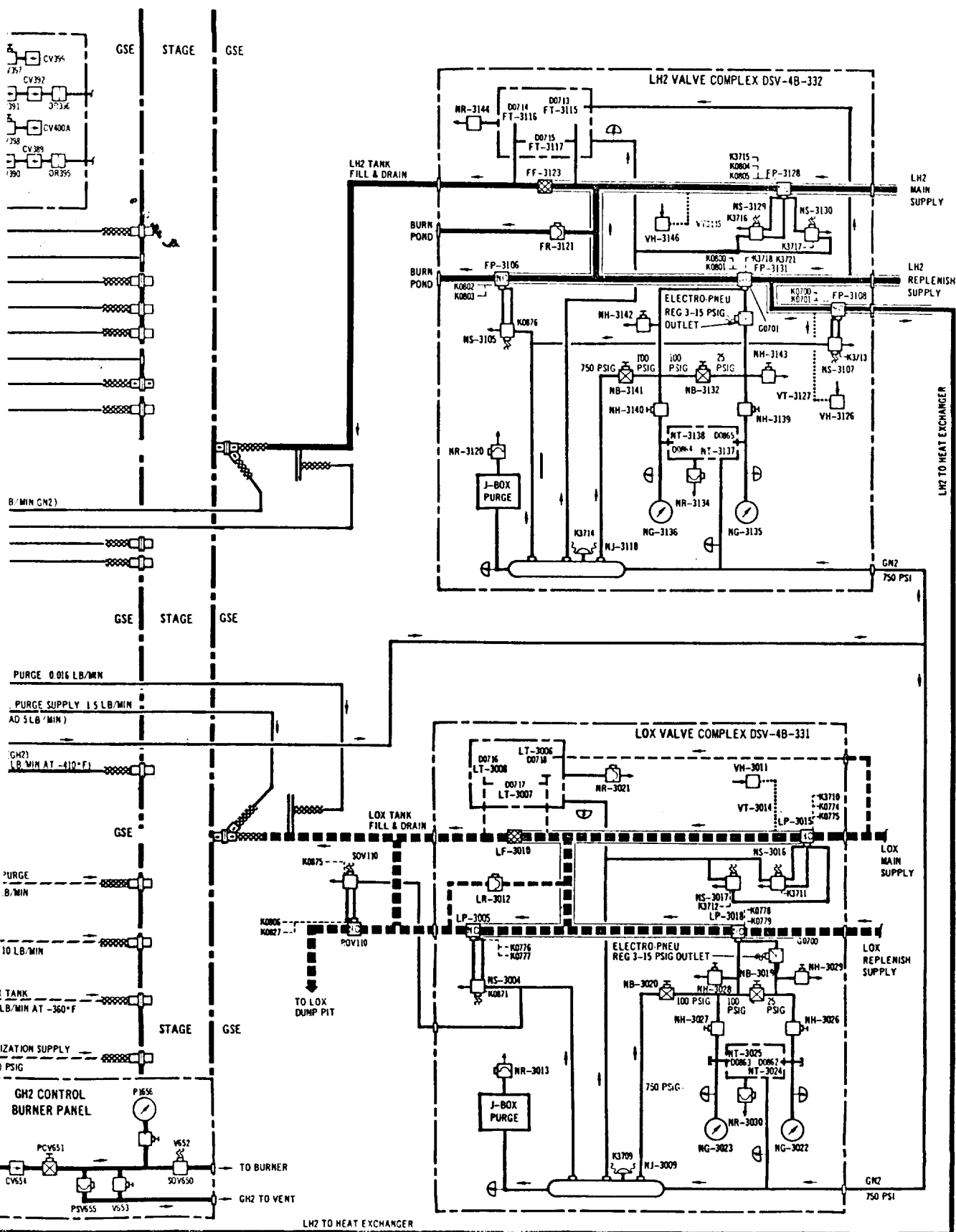


Figure 3-2. Facility Propellant and Pneumatic Loading Systems



4. COUNTDOWN OPERATIONS

The S-IVB-207 stage acceptance firing was successfully accomplished during CD 614074 on 19 October 1966. All phases of the acceptance test countdown are reviewed and evaluated in the following paragraphs, which include discussions of the prefiring checkout, propellant loading, and ground support and facility operation.

4.1 Countdown 614074

Countdown 614074 was initiated on 18 October 1966 and was completed the following day for a satisfactory stage acceptance firing. The countdown was performed with only minor problems encountered; all problems were resolved without a delay in countdown time. The chiltdown shutoff valve failed to open fully during the terminal count; however, valve operation was verified after the chiltdown pump was cycled. LH2 loading was nominal, but a leak in the LOX transfer system necessitated cycling of the LOX transfer line shutoff valve after loading was completed. The propellant tank relief valve checks were performed satisfactorily; the stage pneumatic systems were pressurized; and the automatic terminal count was initiated. The automatic sequence was satisfactory and resulted in a successful firing of 447 sec. Significant countdown times are presented below:

<u>Event</u>	<u>Time</u>
Simulated liftoff (T_0)	1116:15.000 PDT
Engine Start Command (ESC)	T_0 +150.863 sec
Engine Cutoff Command (ECC)	T_0 +598.940 sec

4.2 Checkout

The modifications, procedures, and checkouts performed for the acceptance firing were initiated on 31 August, upon receipt of the stage at the Sacramento Test Center, and were continued through 17 October when the stage was ready for the acceptance firing. The handling and checkout procedures that were used for the prefiring and postfiring checkouts are described in Douglas Report No. SM-56453, Narrative End Item Report on Saturn S-IVB-207, dated December 1966.

The integrated systems test was completed on 5 October to check out the automatically controlled equipment of the stage, pneumatic consoles, and propellant sleds. The simulated static firing was satisfactorily performed on 11 and 12 October to verify the countdown procedure.

4.3 Cryogenic Loading

The S-IVB-207 stage was successfully loaded with LOX, LH2, and cold helium. Satisfactory temperature and pressure levels were attained in all systems, although it was necessary to use the LOX transfer line shutoff valve to shut off flow because of a severe leak past the LOX main fill valve.

4.3.1 LOX Loading

The LOX loading preparations were conducted as specified in Task 41 of the Countdown Manual, and computer controlled loading operations were initiated. LOX loading was inadvertently started early due to a seat leak in the LOX main fill valve in the facility sled complex. Loading began when the LOX fill and drain valve was opened during the latter part of the preloading 15-min ASI LOX dome purge sequence. LOX level was at approximately 6 percent when the computer sequenced the LOX main fill valve to topping position for initiation of fill. The LOX fill and drain valve had been open 8 min at that time, which indicated that the seat leak was roughly equivalent to having the LOX main fill valve in the topping position. The leak necessitated cycling of the LOX transfer line shutoff valve for replenishing after propellant loading was completed. Loading data are presented in figure 4-1.

4.3.2 LH2 Loading

The LH2 loading preparations were completed and the operation initiated as specified in Task 42 of the Countdown Manual. The loading was satisfactorily completed without incident in 31 min 55 sec. Loading data are presented in figure 4-2.

4.3.3 Cold Helium Loading

Cold helium was loaded after the completion of LH2 loading. Satisfactory temperatures and pressures were obtained. Data are presented in table 4-1 and figure 4-3.

4.4 GSE Performance

4.4.1 Helium Supply System

The helium supply system functioned adequately. Propellant tank prepressurization, thrust chamber chilldown, and loading of the cold helium spheres and the stage and engine control sphere were all satisfactorily accomplished. Data are presented in figures 4-1 through 4-7.

4.4.2 GH2 Supply System

The GH2 supply system performed adequately; however, at approximately $T_0 - 600$ sec, it was necessary to vent the supply regulator dome loader in order to obtain the required supply pressure. Start sphere chilldown and loading were satisfactorily accomplished. At Engine Start Command, the engine start sphere conditions were within the required limits. Data are presented in figure 4-5.

4.5 Terminal Countdown

The major events of the terminal countdown were engine conditioning and final replenishing and prepressurization of the propellant tanks. They included final addition of helium to the cold helium spheres and the stage pneumatic control sphere; chilldown of the thrust chamber, engine start sphere, and engine pumps; and pressurization of the start sphere.

The terminal count started with the automatic sequence at $T_0 - 25$ min and proceeded through the scheduled events without incident. The final portion of the terminal count commenced with the initiation of propellant tank prepressurization at $T_0 - 159$ sec; final propellant replenishing was completed by $T_0 - 6$ sec. Cold helium sphere fill was terminated at $T_0 - 5.6$ sec and engine pump purges at $T_0 + 90.0$ sec, approximately as planned.

4.6 Holds

All problems were resolved without a delay in countdown time.

TABLE 1
COLD HELIUM LOADING DATA

S-IVB STAGE	COUNTDOWN	INITIAL PRESSURE (psia)	TIME* TO ACHIEVE 3,000 PSIA (sec)	TIME* TO ACHIEVE 50 DEG R (sec)	PRESSURE AT T ₀ (psia)	TEMPERATURE AT T ₀ (deg R)	LOADED MASS (lbm)
201	614040 614047	1,500 750	200 400	900 860	3,200 3,240	40.0 40.4	342 370
202	614048 614050	760 785	500 670	920 1,030	3,190 3,100	39.5 38.5 (H/W) 41.5 (T/M)	371 346
203	614054 614055† 614056	DNA 734-1,415 750	DNA N/A-1,153 756	DNA 716-664 940	DNA N/A-2,990 3,000	DNA N/A-41 42.0	DNA 334 330
204	614059	730	300	1,000	3,165	41.2	337
501	614061 614063	645 730	550 350	1,080 1,020	3,185 3,155	40.0 40.0	346 340
205	614064	830	354	914	3,050	39.5	338
502	614067	900	340	1,007	3,150	40.2	336
206**	614070	960	4,040	1,265	3,020	40.0	251
207**	614074	1,485	2,000	700	3,060	39.0	254

* - Elapsed time after start of cold helium loading

** - S-IVB-206 and -207 stages utilized only six cold helium spheres.

† - After the cold helium spheres attained 2,920 psia, they were vented to 1,500 psia to permit repairs to the gas heat exchanger relief valves. The spheres were then repressurized.

DNA - Data not available

N/A - Not applicable

H/W - Hardwire

T/M - Telemetry

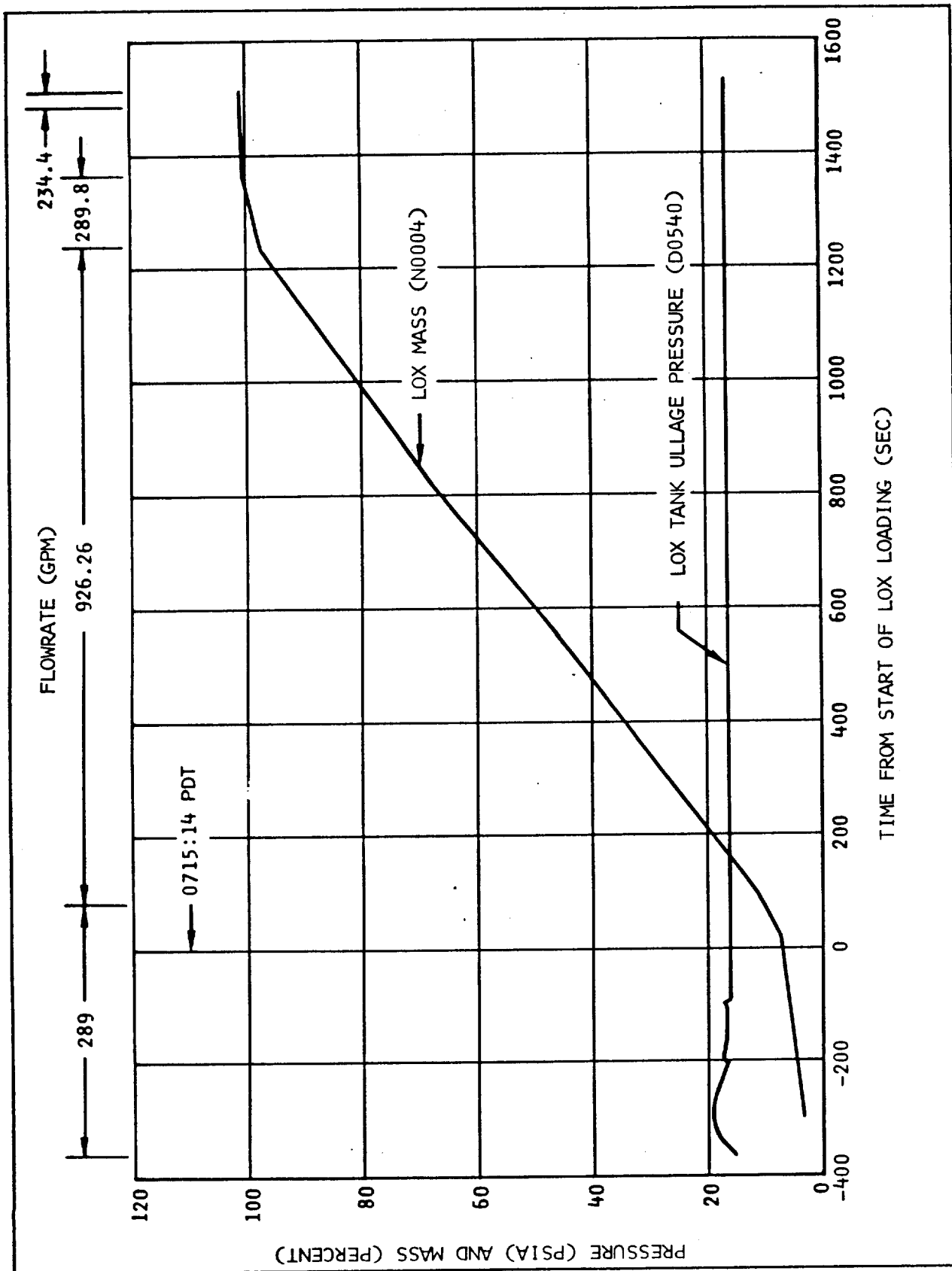


Figure 4-1. LOX Tank Loading

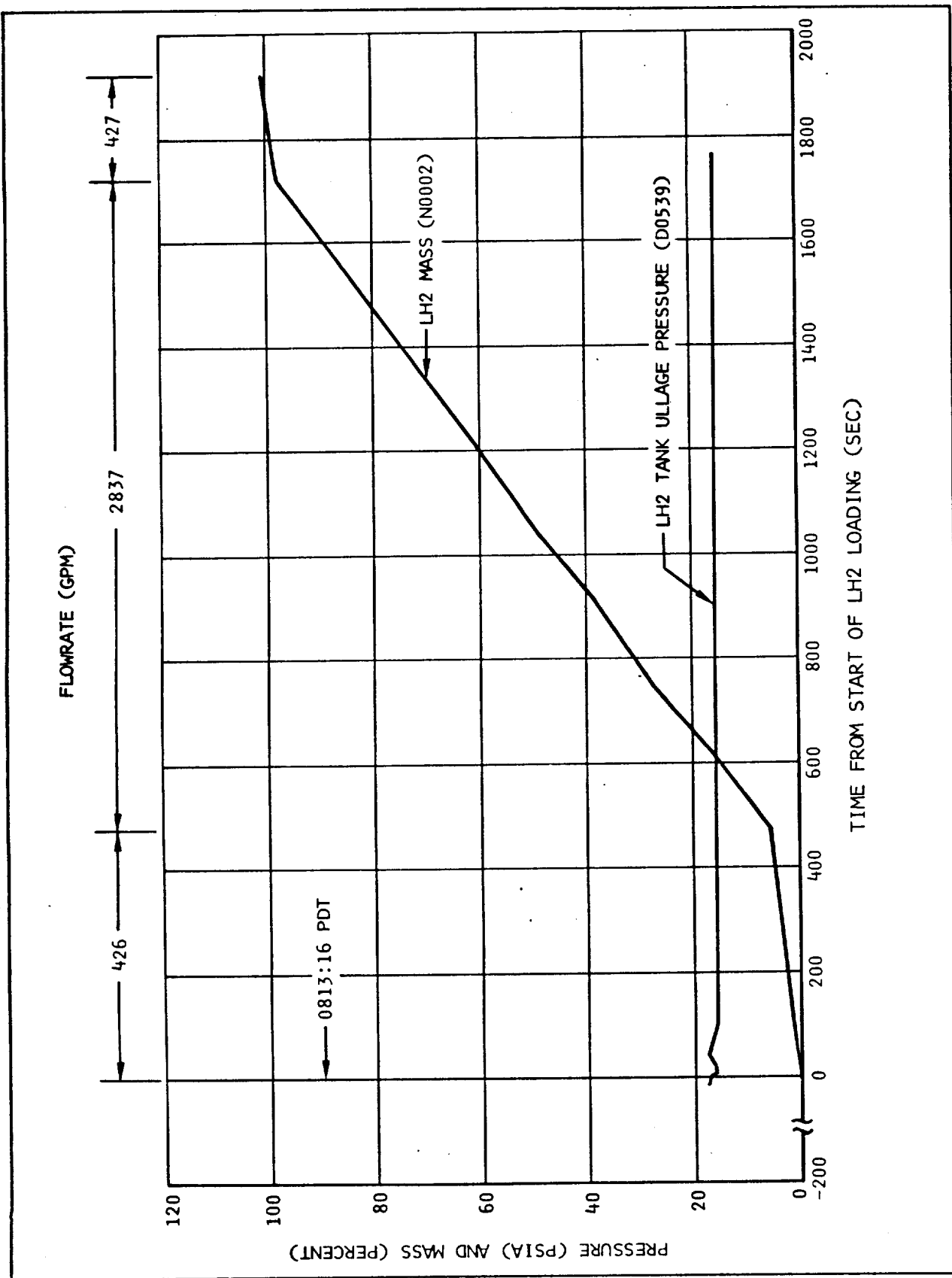


Figure 4-2. LH2 Tank Loading

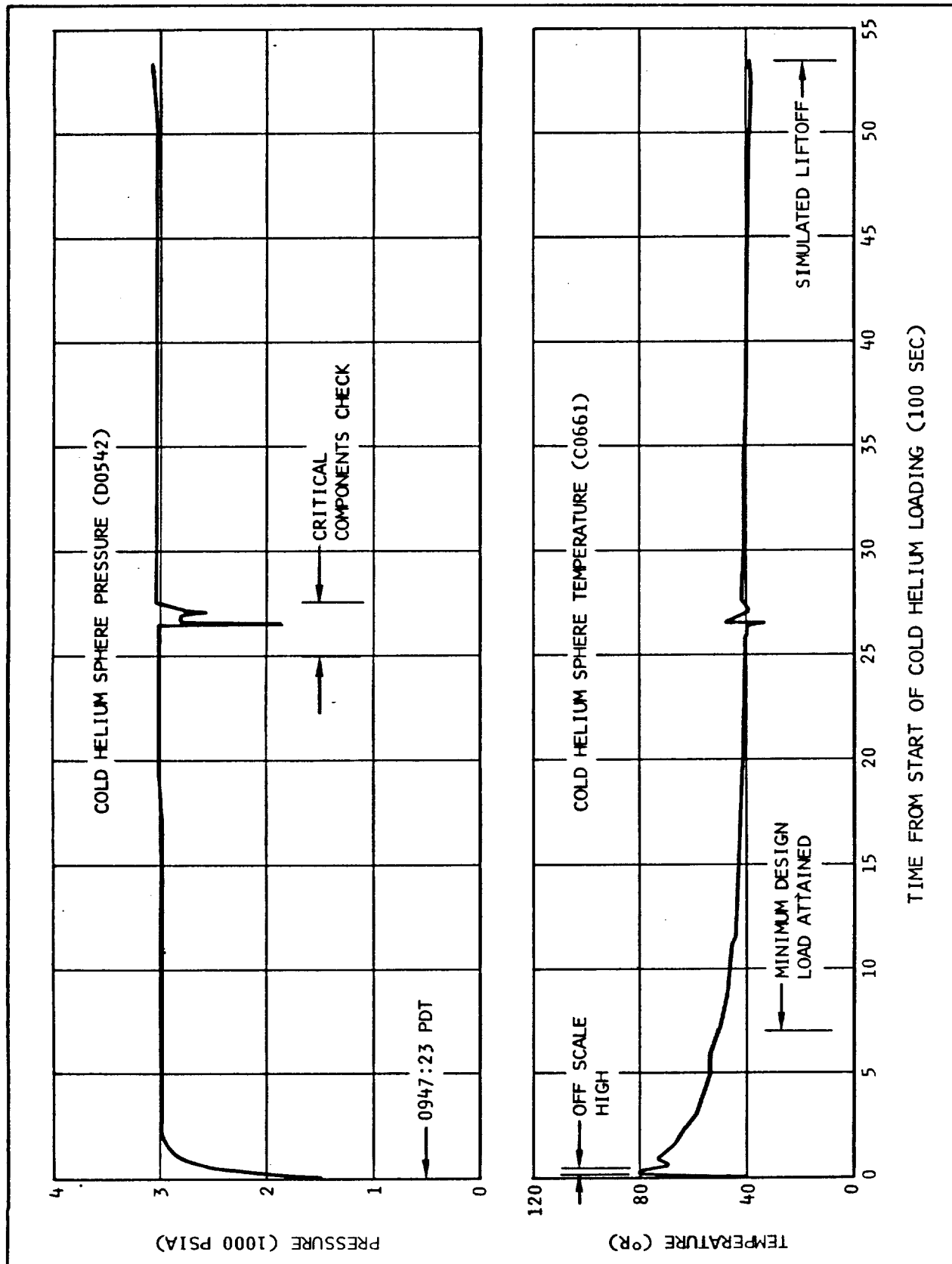


Figure 4-3. Cold Helium System Loading

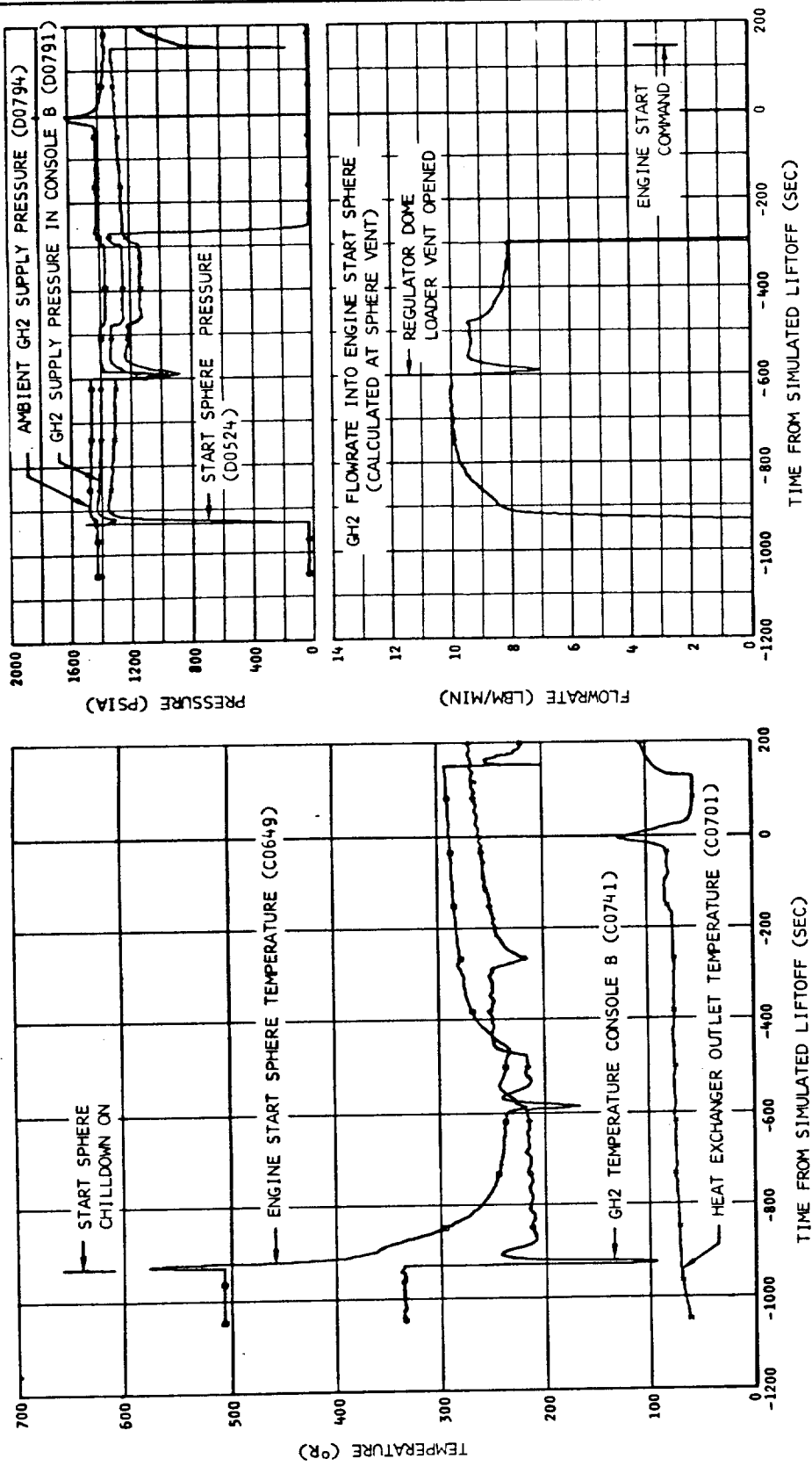


Figure 4-4. GSE Performance During Engine Start Sphere Chilldown and Loading

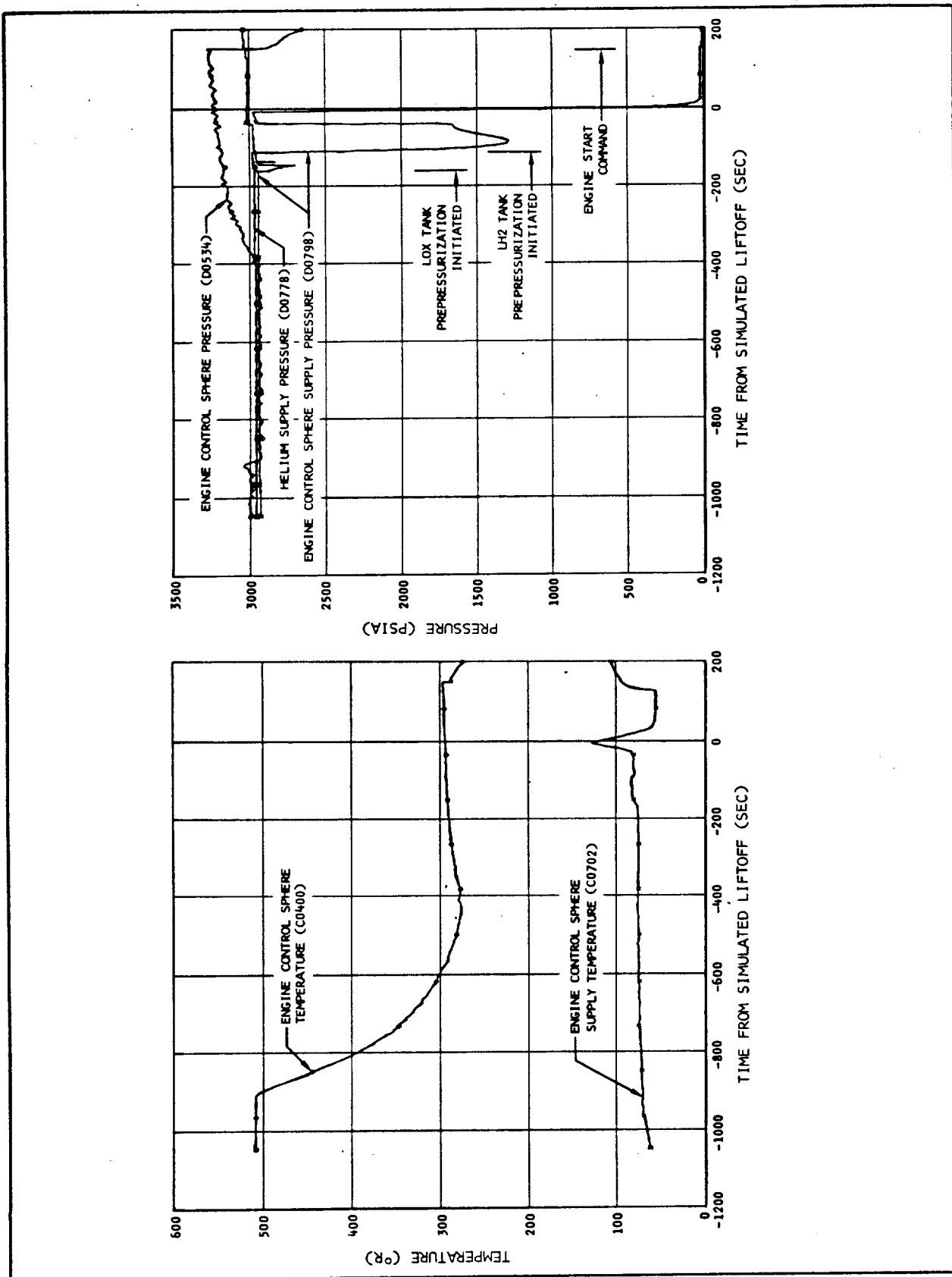


Figure 4-5. GSE Performance During Engine Control Sphere Loading

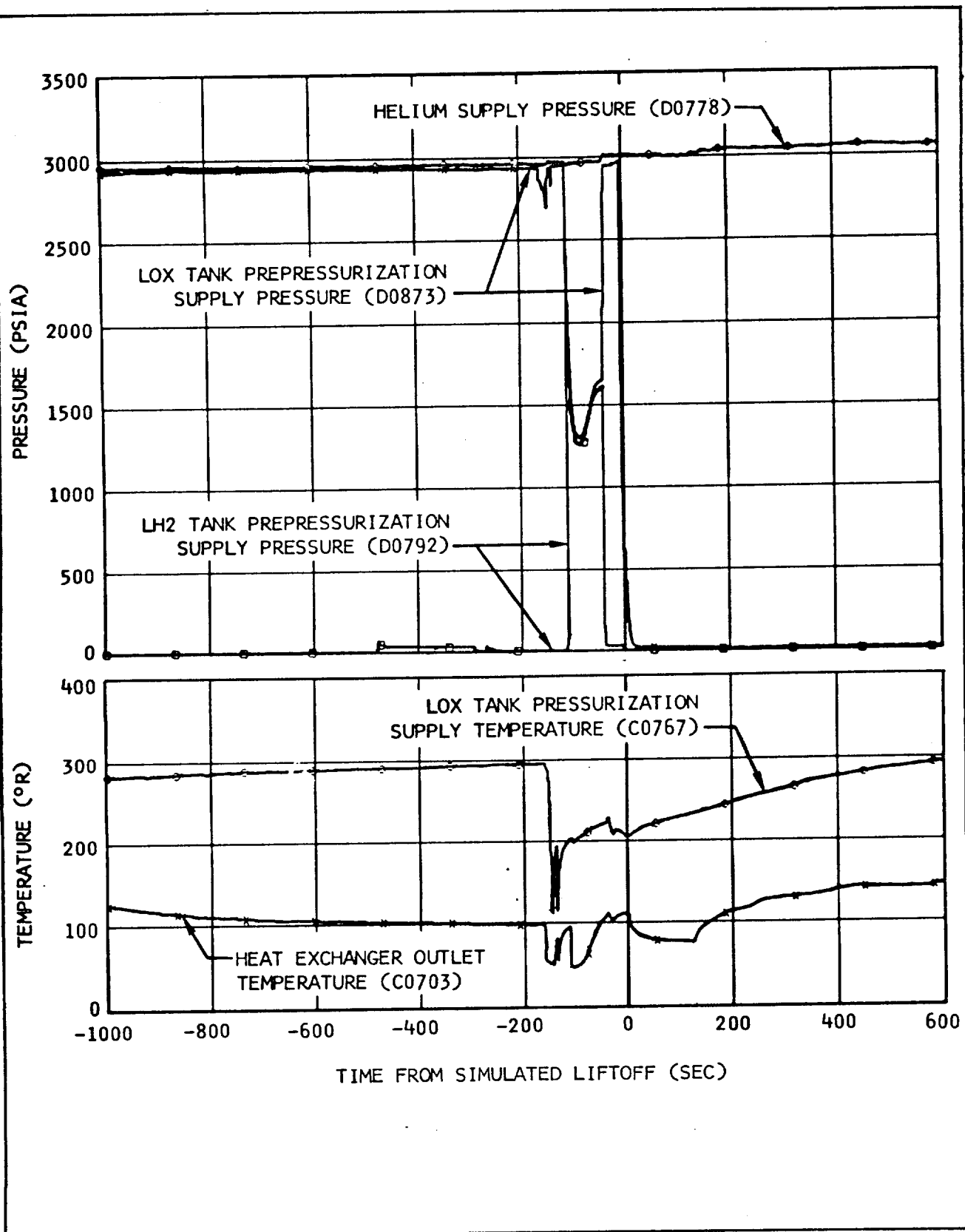


Figure 4-6. GSE Performance During LOX and LH2 Tank Prepressurization

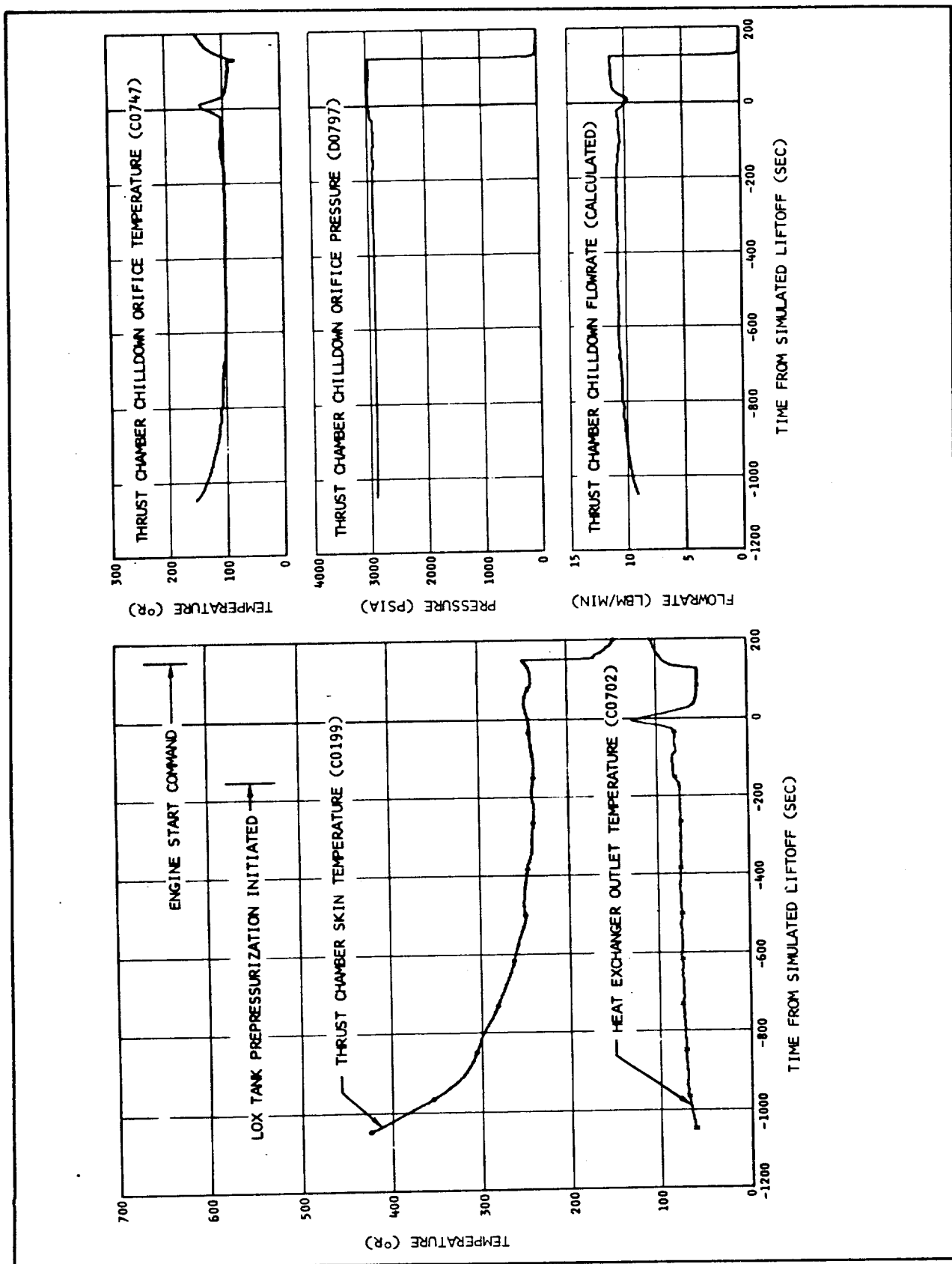


Figure 4-7. GSE Performance During Thrust Chamber Chilldown

5. SEQUENCE OF EVENTS

The S-IVB-207 stage acceptance firing sequence of events is presented in table 5-1. Event times from three data sources are included in the table. These sources were Digital Events Recorder (DER/CAT 57), PCM/FM Sequence (CAT 42), and PCM/FM Digital Tabulation (PCM/TAB/CAT 45). Accuracies of the listed events are as follows:

<u>DATA SOURCE</u>	<u>ACCURACIES</u>
Digital Events Recorder (DER/CAT 57)	+0, -1 ms
PCM/FM	
Discrete Bi-Level (CAT 42)	+0, -9 ms
Digital Tabulation (CAT 45)	
Prime	+0, -9 ms
Submultiplex	+0, -84 ms

TABLE 5-1 (Sheet 1 of 6)
SEQUENCE EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)	PCM/FM SEQUENCE (CAT 42)	PCM/FM DIGITAL TABULATION (CAT 45)
Launch Automatic Sequence Start	31	T _o -1500	T _o -1500	T _o -1500
Start Tank Purge Supply Open		-1231.276		
LOX Dome Purge Off		-1199.867		
Thrust Chamber Purge Closed		-1199.485		
Thrust Chamber Chilldown Open		-1199.345		
Start Tank Purge Supply Closed		-933.999		
Start Tank GH2 Fill Supply Open		-930.049		
Aux Hydraulic Pump On		-609.100		
Aux Hydraulic Pump Coast Mod Off		-609.1		
LOX Chilldown Pump On		-308.749		
LH2 Chilldown Pump On		-305.561		
LH2 Prevalve Closed		-301.930	-301.878	
LOX Prevalve Closed		-301.855	-301.794	
Eng Start Tank GH2 Fill Closed		-268.412		
Eng Start Tank Supply Vent Closed		-268.263		
Cold Helium Crossover Closed		-166.874		
Cold Helium Shutoff Valve Open		-159.890		
LOX Tank Vent Valve Closed		-159.511	-159.472	
LH2 Tank Vent Valve Closed		-110.252	-110.234	
Cold He Reg Backup Sw Enable		-31.351		
LH2 Directional Vent Flt Position		-30.933		

TABLE 5-1 (Sheet 2 of 6)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)	PCM/FM SEQUENCE (CAT 42)	PCM/FM DIGITAL TABULATION (CAT 45)
Internal Power Transfer		-26.215		
LOX Fill & Drain Valve Closed		-7.528	-7.492	
LH2 Fill & Drain Valve Closed		-5.970	-5.992	
Cold He Bottle Supply Off		-5.681		
Eng Control Bottle Fill Closed		-5.574		
Simulated S-IVB/IB Liftoff (T_0)		*0.000		
Inflight Cal On		91.399		
Inflight Cal Off		92.507		
Ullage Rocket Chg On Command	54	141.863		142.0
EBW Charge 1-1				142.0
EBW Charge 1-2				142.0
EBW Charge 2-1				142.0
EBW Charge 2-2				142.0
EBW Charge 3-1				142.0
EBW Charge 3-2				142.0
Ullage Rocket Fire Command	56	146.238		
EBW Fire 1-1			146.270	146.4
EBW Fire 1-2			146.270	146.4
EBW Fire 2-1			146.278	146.4
EBW Fire 2-2			146.278	146.4
EBW Fire 3-1			146.278	146.4

* T_0 = 1116:15:000 PDT

TABLE 5-1 (Sheet 3 of 6)
SEQUENCE EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)	PCM/FM SEQUENCE (CAT 42)	PCM/FM DIGITAL TABULATION (CAT 45)
EBW Fire 3-2			146.278	146.4
LH2 Prevalve Open		149.085	149.170	
LOX Prevalve Open		149.133	149.170	
Engine Cutoff Command Off	13	149.940		
Engine Cutoff Command On (Dropout)		149.946		
Chilldown Pump Discharge Valve Closed Command		150.191		
LH2 Chilldown Pump Off Command	59	150.258		
LH2 Chilldown Pump Off		150.264		
LOX Chilldown Pump Off Command	23	150.363		
LOX Chilldown Pump Off		150.369		
LH2 Chilldown Valve Closed		150.443		
LOX Chilldown Valve Closed		150.448		
Engine Start Command (ESC)		150.863*		
Ignition Phase Control Solenoid Energ		150.864	150.868	
Thrust Chamber Spark Sys On		150.864	150.868	
Gas Generator Spark On		150.864	150.868	
Helium Control Solenoid Energized		150.865	150.868	
Engine Ready Signal Off		150.867	150.928	
Main Fuel Valve Closed (Dropout)		150.913		
Main Fuel Valve Open		150.953	151.011	

* ESC = T₀ +150.863

TABLE 5-1 (Sheet 4 of 6)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)	PCM/FM SEQUENCE (CAT 42)	PCM/FM DIGITAL TABULATION (CAT 45)
Ignition Detected	27	151.002	151.001	
Engine Start Off Command		151.434		
Engine Start Off		151.438		
Start Tank Discharge Valve Close (Dropout)		151.650		
LOX Tank Flight Pressure System On Command		151.715		
Start Tank Discharge Valve Open		151.739	151.761	
Mainstage Control Solenoid Energized		151.943	151.943	
Gas Generator Valve Closed (Dropout)		152.037		
Main Oxidizer Valve Closed (Dropout)		152.044		
Start Tank Discharge Valve Open (Dropout)		152.062	152.095	
Gas Generator Valve Open	68	152.164	152.178	
Oxidizer Turbine Bypass Valve Open (Dropout)		152.197	152.270	
Oxidizer Turbine Bypass Valve Closed		152.394	152.436	
Mainstage Pressure Switch Depress 1 (Dropout)		153.508	153.537	
Mainstage Pressure Switch Depress 2 (Dropout)		153.510	153.537	
Mainstage OK Press Sw 1 - Press		153.510	153.537	
Mainstage OK Press Sw 2 - Press			153.520	
Engine Burn No. 1 On Command		153.847		
Engine Burn No. 1 On		153.855		
Main Oxidizer Valve Open		154.345	154.428	
Gas Generator Spark System Off		155.242	155.243	

TABLE 5-1 (Sheet 5 of 6)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)	PCM/FM SEQUENCE (CAT 42)	PCM/FM DIGITAL TABULATION (CAT 45)
Thrust Chamber Spark System Off		155.243	155.243	
PU Activate Command	5	157.028		
PU Activate		157.032		
Ullage Rocket Jettison Charge On Command	55	174.985		175.0
EBW Charge 1				175.0
EBW Charge 2				
Ullage Rocket Jettison Fire On Command	57	178.116		
Ullage Jettison Charge Command Reset	88	178.205		
EBW Fire 1			178.193	178.2
EBW Fire 2			178.193	178.2
Ullage Jettison Fire Command Reset	73	178.292		
Range Safety Off Enable On Command	85	259.173		
Auxiliary Hydraulic Pump Off Command	29	335.876		
Auxiliary Hydraulic Pump Off		335.880		
Auxiliary Hydraulic Pump On Command	28	452.148		
Auxiliary Hydraulic Pump On		452.151		
First Burn Relay Off Command	69	452.235		
First Burn Relay Off		452.241		
Point Level Sensor On Command	97	591.215		
Non-Programmed Engine Cutoff (ECC)		598.940*		
Cutoff Signal Energized			598.975	

* ECC = T₀ 598.940

TABLE 5-1 (Sheet 6 of 6)
SEQUENCE OF EVENTS

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)	PCM/FM SEQUENCE (CAT 42)	PCM/FM DIGITAL TABULATION (CAT 45)
Ignition Phase Control Solenoid De-energized	12	598.942	598.949	
Mainstage Control Solenoid De-energized		598.942	598.949	
Gas Generator Valve Open (Dropout)		598.974	598.975	
Engine Cutoff On Command		598.986		
Engine Cutoff Command On		598.990		
Main Oxidizer Valve Open (Dropout)		599.036	599.059	
Gas Generator Valve Closed		599.018		
Main Fuel Valve Open (Dropout)		599.070	599.142	
Engine Pump Purge Control Valve Open Command		599.068		
Mainstage Pressure Switch 1 Depress		599.108	599.167	
Mainstage Pressure Switch 2 Depress		599.109	599.167	
Main Oxidizer Valve Closed		599.130		
Main Fuel Valve Closed	24	599.250		
Fuel Prevalve Open (Dropout)		599.511	599.550	
Oxidizer Prevalve Open (Dropout)		599.513	599.550	
Helium Control Solenoid De-energized		599.909	599.915	
Fuel Prevalve Closed		599.759	599.800	
Oxidizer Prevalve Closed		599.840	599.884	
Coast Period On Command		600.178		
PU Activate Off Command		601.993		
PU Activate Off		601.996		
Point Level Sensors Disarm Command		602.166		
	79			
	6			
	98			

SECTION 5

SEQUENCE OF EVENTS

SECTION 6

ENGINE SYSTEM

6. ENGINE SYSTEM

The S-IVB-207 acceptance firing was performed with Rocketdyne engine S/N 2056 (figure 6-1) mounted on the stage. The engine performed satisfactorily throughout mainstage operation.

6.1 Engine Chillydown and Conditioning

6.1.1 Turbopump Chillydown

Chillydown of the engine LOX and LH2 turbopumps was adequate to provide the conditions required for proper engine start. An analysis of the chillydown operations is presented in paragraphs 7.3 and 8.2.

6.1.2 Thrust Chamber Chillydown

The thrust chamber skin temperature was 250 deg R at Engine Start Command (ESC) (figure 6-2), well within the engine start requirement of 260 ± 50 deg R; and the LH2 pump demonstrated satisfactory start transient buildup characteristics (figure 6-3). Data are presented in table 6-1. Further information on the chillydown operation and GSE supply system is presented in section 4.

6.1.3 Engine Start Sphere Chillydown and Loading

Chillydown and loading of the engine GH2 start sphere met the objectives ($1,325 \pm 75$ psia and 290 ± 30 deg R). Start sphere performance is graphically presented in figure 6-4. The GH2 supply system performance during start sphere chillydown and loading is described in section 4. The sphere warmup rate from sphere pressurization to blowdown was 1.8 deg R/min. Data are presented in table 6-2. The system demonstrated satisfactory repressurization of the start sphere during engine burn.

6.1.4 Engine Control Sphere Chillydown and Loading

Engine control sphere conditioning was adequate and all objectives were satisfactorily accomplished (figure 6-4). The engine start requirements

of 290 ± 30 deg R and 2,800 to 3,450 psia were met. Significant control sphere performance data are presented in table 6-3.

6.2 J-2 Engine Performance Analysis Methods and Instrumentation

Engine performance for the acceptance firing was calculated by use of computer programs AA89, G105-3, and F823-1. A description of the operation and comparison of the results of each program is presented in table 6-4.

Computer program AA89 was modified to reconstruct the firing by biasing the LOX flowrate by -2.0 lbm/sec, the LH2 flowrate by -0.6 lbm/sec, and the thrust by -1,200 lbf from ESC +120 sec to engine cutoff. These biases were necessary in order to reconstruct the engine performance as reflected in the acceptance firing data.

Several other biases were necessary to correct for known data discrepancies. The main chamber pressure was biased -15 psi, as recommended by Rocketdyne, because of a transducer purge. From an analysis of the raw test pip count data, the engine flowmeter data were biased -3.60 gpm for LOX and +5.90 gpm for LH2.

In the F823 program, coefficients relating gas generator (GG) mixture ratio to LOX turbine inlet temperature were substituted for those relating the GG mixture ratio to the LH2 turbine inlet temperature which are normally used. The substitution was made because the LH2 turbine inlet temperature transducer malfunctioned at approximately ESC +170 sec. The 3-sigma deviation of the relationship (GG mixture ratio as a function of LH2 turbine inlet temperature) is 99.998; whereas, the 3-sigma deviation of the relationship (GG mixture ratio as a function of LOX turbine inlet temperature) is 99.381.

6.3 J-2 Engine Performance

The engine performance was satisfactory throughout the mainstage operation. Plots of selected data used as inputs to the computer programs

listed in table 6-4 are presented in figures 6-5 through 6-11. The engine propellant inlet conditions are presented in sections 7 and 8. The engine performance was reconstructed from Engine Start Command to Engine Cutoff Command (ECC) by the computer programs described in table 6-4. Necessary modifications to the data and computer programs were made as indicated in paragraph 6.2. The average performance values from each program are shown in table 6-5. The performance profiles of the programs, as well as the composite profiles, are shown in figures 6-12 and 6-13. The composite values constitute the final engine performance values as presented in table 6-5.

The average results of these programs agreed with the following accuracies:

<u>Parameter</u>	<u>Deviation (%)</u>
Thrust	0.416
Total flow	0.815
Specific impulse	0.516
Engine mixture ratio	1.722

6.3.1 Start Transient

The J-2 engine start transient was satisfactory. A summary of engine performance is presented in the following table:

<u>Parameter</u>	<u>Acceptance Firing</u>	<u>Log Book</u>
Time to 90 percent performance level (sec)	3.382	2.32*
Thrust rise time (sec)	2.239	1.82
Total impulse (lbf-sec)	204,694	154,497**
Maximum rate of thrust increase (lbf/10 ms)	8,147	40,000***

*Referenced to start tank discharge valve. Acceptance firing start tank discharge control solenoid energized at 639 ms.

**Based on stabilized thrust at null PU and standard altitude conditions.

***Maximum allowable.

Thrust buildup to the 90 percent performance level (thrust chamber pressure at 618 psia) was within the maximum and minimum thrust bands as shown in figure 6-14. The deviation in total impulse from the log book is due to the longer thrust rise time (time from first indication of thrust to the 90 percent performance level) during the acceptance firing. Figure 6-14 shows the thrust chamber pressure during start transient and the thrust buildup to the 90 percent performance level for the acceptance firing as determined by computer program F839. As expected, there was no thrust overshoot during the start transient.

6.3.2 Steady State Performance

During the steady state portion of the S-IVB-207 stage acceptance firing, there was indication of a performance shift at approximately ESC +126 sec, as can be seen in the performance profiles in figure 6-12. The average performance values prior to and after the shift are given in table 6-5. Analysis of the data indicates that the shift may have been due to a change in the flow resistance of the gas generator LOX bootstrap line. This resistance change is caused by an alignment shift of the gas generator LOX orifice during engine operation. This has been a recurring problem, and a Rocketdyne modification to correct the situation is in test; however, because the shift is usually within specifications (± 3 percent for thrust), no decision has been made to incorporate the change.

Table 6-5 compares the overall average performance values for steady state operation with the predicted values. This table also compares the average performance during the closed PU valve portion of the test with the prediction and shows that the actual values prior to 126 sec were in close agreement with the prediction. The performance deviations caused by the shift did not seriously affect the propellant consumption rate and resulted in a small PU valve cutback deviation (see section 10).

The amount of propellants consumed from Engine Start Command to Engine Cutoff Command (ESC +448.077 sec) was 35.379 lbm of LH2 and 192,702 lbm of LOX as determined from engine flow integral analysis. The total impulse generated was 97.11×10^6 lbm-sec. Extrapolating the usable propellants indicated that a LOX depletion would have occurred 3.806 sec after Engine Cutoff Command for a total burn to depletion of 451.883 sec, as compared to the predicted value of 462.864. The 10.981 sec deviation was caused by the extended operation with the PU valve closed which raised the average rate of LOX consumption.

The engine thrust variations during the acceptance firing are presented in table 6-6. Expanded thrust plots during the periods discussed are presented in figures 6-15 and 6-16. Comparison is made to acceptance firing thrust history predictions and to Marshall Space Flight Center suggested allowable limits for flight. These limits do not apply to acceptance firing performance and are presented for reference purposes only. It should be noted that these limits are more stringent than those for previous S-IVB/IB stages. Thrust variations during flight will be modified by flight dynamics effects on stage operation. Thrust variations were noted during the following four phases of engine operation:

- a. Hardover or maximum engine mixture ratio operation
(EMR = 5.5/1.0)
- b. Transient phase (PU valve cutback +50 sec to ECC +70 sec)
- c. Final 40 sec of burn
- d. Final 70 sec of burn

The thrust variations during the hardover operation were within the suggested allowable limits for normal operation. Normal operating thrust variations during this time period are caused by engine stabilization and stage perturbations including the effects of variations

in propellant supply conditions. The internal engine performance shift which occurred at ESC +120 sec resulted in a rate of change in thrust of -835 lbf/sec which deviated from the allowable limits during this period of operation.

The time period from PU valve cutback +50 sec to ECC -70 sec was non-existent during this firing because of the late PU valve cutback. The deviations causing the late PU valve cutback are discussed in section 10.

The time period from ECC -70 sec to Engine Cutoff Command includes the transient performance results. The transient performance during this period was caused by the late PU valve cutback mentioned. Because of the late cutback, the MSFC suggested allowable limits on thrust variations were exceeded in all categories. Acceptance firing data will aid in the flight calibration of the PU system in order to nominally eliminate the deviations in the PU valve cutback.

The time period from ECC -40 sec to Engine Cutoff Command is reported in addition to the normal periods discussed in an effort to show a more stable period of engine operation. The thrust variations during this period are influenced primarily by movements of the PU valve and, to a secondary degree, by variations in stage performance. The thrust variations were within the suggested flight limits for the maximum rate of change and for the deviation from predicted mean slope. Deviations in the other categories are attributed to the transient operation caused by the late PU valve cutback.

6.3.3 Cutoff Transient

The time lapse between engine cutoff, as received at the J-2 engine, and thrust decrease to 11,250 lbf was not within the maximum allowable time (800 ms) for the acceptance firing as shown in the following table.

	<u>Acceptance</u>	<u>Log Book</u>
Thrust decrease to 11,250 lbf (ms)	825	385
Total impulse (lbf-sec)	43,782*	34,220**

*PU valve at -5.02 deg

**PU valve at null position; standard altitude conditions, average of tests 313-011 and 313-012.

The performance values presented are not in satisfactory agreement with the log book or the Rocketdyne J-2 Engine Manual No. R-3825-1 (0.340 \pm 0.030 sec and 38,100 \pm 3,000 lbf-sec, based on a main LOX valve temperature of 0 deg F with PU valve in the null position, and defined from cutoff signal to 5 percent of rated thrust). Stage performance during flight should not be adversely affected by these conditions.

The deviation in cutoff impulse to 11,250 lbf from Rocketdyne nominal values (which are based on thrust load cell data) are probably caused by a time lag in the chamber pressure measurement from which computer program F839 calculates cutoff impulse. The time lag, which has been discussed in previous reports, is under investigation by the engine manufacturer. The actual cutoff impulse was probably less than that calculated by program F839. Figure 6-17 presents the thrust chamber pressure data for the cutoff transient and the cutoff transient thrust. Figure 6-18 presents accumulated cutoff impulse from engine cutoff to 11,250 lbf thrust for the acceptance firing.

6.4 Engine Sequencing

The engine sequencing was satisfactory throughout the acceptance firing and compatible with the engine logic and the acceptance firing test plan. Figure 6-19 presents the engine start sequence for the acceptance firing; table 6-7 presents the time of significant events during the firing and compares them to the nominal values.

An orifice was installed in the gas generator valve control line to delay the opening of the valve by approximately 65 ms, thereby eliminating the high line pressure effects on the main LOX valve. Satisfactory results were obtained. Because of the low sampling rate (12 sps) and the lack of FM data, all sequence of events data are only accurate to ± 80 ms.

6.5 Component Operation

All of the J-2 engine components performed satisfactorily during the acceptance firing. The main LOX valve required 2.63 sec to open. This was satisfactory based on the specified time for dry valve operation. The second stage travel was devoid of line pressurization disturbances indicating the effectiveness of the modification to retard the opening of the gas generator valve. The main LOX valve opening time data were as follows:

<u>Parameter</u>	<u>Specification</u>	<u>Dry</u>	<u>Acceptance</u>
First stage travel (ms)	50 \pm 20	49	50
Plateau (ms)	460 \pm 55	540	500
Second stage travel (ms)	1600 \pm 75	1554	2180
Total (ms)	2110 \pm 150	2143	2630

6.6 Engine Vibration

Four vibration measurements were monitored on the engine which included one at the LOX turbopump, one at the LH2 turbopump, and two on the combustion chamber dome. The data from these measurements are shown in figure 6-20. The vibration levels at these locations were comparable to those measured on past acceptance firings.

TABLE 6-1
THRUST CHAMBER CHILLDOWN

	S-IVB-207	S-IVB-206	S-IVB-205
Engine start requirement (deg R)	250 ±50	250 ±50	250 ±50
Thrust chamber chilldown initiated (sec)	-1,200	-1,201	-1,201
Thrust chamber chilldown terminated (sec)	+127	+126	+117
Thrust chamber temperature (C0199) at end of chill-down (deg R)	240	232	249
Thrust chamber temperature at engine start (deg R)	250	235	258

TABLE 6-2
ENGINE START SPHERE PERFORMANCE

	TEMPERATURE (DEG R)			PRESSURE (PSIA)			MASS (LBM)		
	S-IVB -207	S-IVB -206	S-IVB -205	S-IVB -207	S-IVB -206	S-IVB -205	S-IVB -207	S-IVB -206	S-IVB -205
Engine start requirement		290 ±30		1,325 ±75					
Engine Start Command	292	252	291	1,312	1,346	1,266	3.32	3.95	3.23
After sphere blowdown	200	156	200	169	184	190	0.66	0.83	0.67
Engine cutoff	205	207	235	1,300	1,463	1,350	3.85	5.24	4.22
Total GH2 usage during start							2.66	3.12	2.56

TABLE 6-3
ENGINE CONTROL SPHERE PERFORMANCE

	TEMPERATURE (DEG R)			PRESSURE (PSIA)			MASS (LBM)		
	S-IVB -207	S-IVB -206	S-IVB -205	S-IVB -207	S-IVB -206	S-IVB -205	S-IVB -207	S-IVB -206	S-IVB -205
Engine start requirement		290 ±30		2,800 to 3,450					
Engine Start Command	296	261	303	3,264	3,150	3,171	1.98	2.15	1.91
Engine cutoff	252	217	248	2,187	2,057	1,950	1.61	1.81	1.48
Total helium usage							0.37	0.42	0.43

TABLE 6-4
COMPARISON OF COMPUTER PROGRAM RESULTS

PROGRAM	INPUT	METHOD	RESULTS
AA89	LOX AND LH2 pump inlet pressures and temperatures, PU valve position, and engine tag values	Influence equations relate nominal inlet conditions to nominal performance. Using actual inlet conditions, PU valve position and engine tag values, the actual performance is simulated.	$F = 218,428.8 \text{ lbf}$ $\dot{W}_T = 514,413 \text{ lbf/sec}$ $I_{sp} = 424.776 \text{ sec}$ $MR = 5.419$
G105 Mode 3	LOX and LH2 flowmeters, pump discharge pressures and temperatures, chamber pressures, chamber thrust area	Flowrates are computed from flowmeter data and propellant densities. The C_F is determined from equation $C_F = f(P_c, MR)$ and thrust is calculated from equation $F = C_F A_t P_c$.	$F = 217,518.79 \text{ lbf}$ $\dot{W}_T = 510.591 \text{ lbf/sec}$ $I_{sp} = 426.099 \text{ sec}$ $MR = 5.415$
F823 Mode 1	Thrust chamber pressure, gas generator pressure, LH2 injection temperature, LH2 pump discharge temperature, LH2 turbine inlet temperature	Total flows of the thrust chamber and gas generator are calculated as a function of respective chamber pressures. Mixture ratio of the chamber is calculated as a function of temperature rise of the LH2 in the cooling jacket, and mixture ratio of the GG is calculated as a function of turbine inlet temperature. Thrust is calculated from the equation $F = C_F A_t P_c$.	$F = 217,785.96 \text{ lbf}$ $\dot{W}_T = 510.223 \text{ lbf/sec}$ $I_{sp} = 426.981 \text{ sec}$ $MR = 5.509$
F839	Thrust chamber pressure, chamber throat area	The C_F is computed from equation $C_F = f(P_c)$ and thrust is computed from equation $F = C_F A_t P_c$. The impulse is determined from integrated thrust.	Refer to paragraphs 6.3.1 and 6.3.3.

TABLE 6-5

ENGINE PERFORMANCE

PARAMETER	ESC+20 TO ESC+120 SEC			CLOSED PU VALVE			REFERENCE MIXTURE RATIO			OVERALL PERFORMANCE			PERFORMANCE SHIFT (ESC+120 SEC)	
	ACTUAL	PRE-DICTED	% DEV	ACTUAL	PRE-DICTED	% DEV	ACTUAL	PRE-DICTED	% DEV	ACTUAL	PRE-DICTED	% DEV	SHIFT	%
Thrust (lbf)	226,141	226,186	0.019	225,068	225,806	0.30	188,880	187,270	-0.90	217,911	213,198	-2.2	-1920.05	0.85
Total flowrate (lbm/sec)	531.89	533.10	0.23	529.54	532.31	0.50	438.76	433.28	-1.3	511.74	500.00	-2.3	-4.40	0.83
LOX flowrate (lbm/sec)	451.17	452.29	0.25	448.99	451.72	0.60	364.56	358.21	-1.8	432.45	421.23	-1.7	-3.404	0.75
LH2 flowrate (lbm/sec)	80.72	80.81	0.11	80.55	80.59	0.05	74.20	75.07	1.2	79.29	78.77	-0.7	-0.999	1.23
Engine mixture ratio	5.589	5.590	0.02	5.574	5.605	0.60	4.917	4.772	-3.0	5.448	5.336	-2.1	+0.028	0.503
Specific impulse (sec)	425.07	424.29	-0.18	425.03	424.20	-0.20	430.49	432.21	0.40	425.95	426.71	0.20	-0.089	0.02

TABLE 6-6
ENGINE THRUST VARIATIONS

TIME PERIOD		HARDOVER	TRANSIENT FROM VALVE CUTBACK +50 SEC TO ECC -70 SEC	FINAL 40 SEC OF BURN	FINAL 70 SEC OF BURN
Mean slope (lbf/sec)	Allowable	--	--	±44	
	Actual	--	--	+90	-75
	Predicted	--	--	N/A	+10
Maximum rate (lbf/sec)	Allowable	±500	±500	±354	
	Actual	-835 ±170	N/A	+180	+525
	Predicted	±100	+120	N/A	+120
Maximum (zero to peak) amplitude (lbf)	Allowable	±2,500	±7,500	±1,000	
	Actual	±1,100	N/A	±2,000	±3,500
	Predicted	±750	±1,000	N/A	±800
Maximum deviation from predicted amplitude of mean slope (lbf)	Allowable	±4,000	±3,000	±3,000	
	Actual	-2,000	N/A	-2,000 at ECC -40	+6,000 at ECC -70
Deviation from predicted rate of mean slope (lbf/sec)	Allowable	--	--	28	
	Actual	--	--	60	85

N/A - Not applicable

TABLE 6-7 (SHEET 1 OF 8)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (MS)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
K0021	*Engine Start Command P/U			0	0	
		K0007	Helium Control Solenoid Enrg P/U	Within 10 ms of K0021	2	
		K0010	Thrust Chamber Spark on P/U	Within 10 ms of K0021	1	
		K0011	Gas Generator Spart on P/U	Within 10 ms of K0021	1	
		K0006	Ignition Phase Control Solenoid Enrg P/U	Within 20 ms of K0021	1	
		K0012	Engine Ready D/O	Within 20 ms of K0006	4	3
		K0126	LOX Bleed Valve Closed P/U	Within 120 ms of K0007	69	67

*Engine ready and stage separation signals (or simulation) are required before this command will be executed. This command also actuates a 640 ±30 ms timer which controls energizing of the start tank discharge solenoid N010 (K0096).

P/U - Pickup

D/O - Dropout

TABLE 6-7 (SHEET 2 OF 8)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (MS)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
		K0127	LH2 Bleed Valve Closed P/U	Within 120 ms of K0007	55	53
		K0020	ASI LOX Valve Open P/U	Within 20 ms of K0006	35	34
		K0119	Main Fuel Valve Closed D/O	60 \pm 30 ms from K0006	50	49
		K0118	Main Fuel Valve Open P/U	80 \pm 50 ms from K0119	90	40
K0008	*Ignition Detected			Within 250 ms of K0021 P/U	139	
K0021	**Engine Start Command D/O			Approx 500 ms from K0021 P/U	575	

*This signal must be received with 1,110 \pm 60 ms of K0021 P/U or cutoff will be initiated.

**This signal drops out after a time sufficient to lock in the engine electrical.

P/U - Pickup

D/O - Dropout

TABLE 6-7 (SHEET 3 OF 8)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (MS)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
K0096	*Start Tank Disc Control Solenoid Enrg	K0123	Start Tank Disc Valve Closed D/O	640 \pm 30 ms from K0021	639	148
K0005	Mainstage Control Solenoid Enrg	K0122	Start Tank Disc Valve Open P/U	100 \pm 20 ms from K0096	787	89
				105 \pm 20 ms from K0123	876	
				450 \pm 30 ms from K0096	1,080	441
		K0096	Start Tank Disc Control Solenoid Enrg D/O	450 \pm 30 ms from K0096	1,081	442
		K0121	Main LOX Valve Closed D/O	60 \pm 20 ms from K0005	1,181	101

*An indication of fuel injection temperature of -150 ± 40 deg F (or simulation) is required before this command will be executed. This command also actuates a 450 \pm 30 ms timer which controls the start of mainstage.

P/U - Pickup

D/O - Dropout

TABLE 6-7 (SHEET 4 OF 8)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (MS)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
		K0116	Gas Generator Valve Closed D/O	75 \pm 25 ms from K0005	1,174	94
		K0122	Start Tank Disc Valve Open D/O	95 \pm 20 ms from K0096	1,199	119
		K0117	Gas Generator Valve Open P/U	190 \pm 40 ms from K0116	1,301	127
		K0124	LOX Turbine Bypass Valve Open D/O	Within 100 ms of K0005	1,334	254
			LOX Turbine Bypass Valve 80% Closed	+150 ms -50 from K0122	1,500	301
		K0123	Start Tank Disc Valve Closed P/U	250 \pm 40 ms from K0122	1,408	209
		K0125	*LOX Turbine Bypass Valve Closed P/U		1,531	

*Within 5,000 ms of K0005 (Normally = 500 ms)

P/U - Pickup

D/O - Dropout

TABLE 6-7 (SHEET 5 OF 8)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (MS)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
K0158	Mainstage Press. Switch No. 1 Depress. D/O				2,646	
K0159	Mainstage Press. Switch No. 2 Depress. D/O				2,646	
K0191	*Mainstage OK				2,647	
		K0120	Main LOX Valve Open P/U	2110 \pm 155 ms from K0005	3,482	2,402
		K0010	Thrust Chamber Spark on D/O	3300 \pm 200 ms from K0010 P/U	4,380	4,379
		K0011	Gas Generator Spark on D/O	3300 \pm 200 ms from K0011 P/U	4,379	4,378

*One of these signals must be received within 4,410 \pm 260 ms from K0021 P/U, or cutoff will be initiated. Signal occurs when LOX injection pressure is 500 \pm 30 psig.

P/U - Pickup

D/O - Dropout

TABLE 6-7 (SHEET 6 OF 8)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (MS)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
K0507 CSS-22	PU Activate Switch P/U			0	6,169	
K0013	Engine Cutoff PU (New time reference)	K0005	Mainstage Control Solenoid Enrg D/O	Within 10 ms of K0140	1	
		K0006	Ignition Phase Control Solenoid Enrg D/O	Within 10 ms of K0140	1	
		K0020	ASI LOX Valve Open D/O		20	
		K0120	Main Oxidizer Valve Open D/O	60 ±15 ms from K0005	95	94
		K0117	Gas Generator Valve Open D/O	75 +25 ms -35 from K0006	33	32
		K0118	Main Fuel Valve Open D/O	90 ±25 ms from K0006	129	128

P/U - Pickup

D/O - Dropout

TABLE 6-7 (SHEET 7 OF 8)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (MS)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
		K0121	Main Oxidizer Valve Closed P/U	120 \pm 15 ms from K0120	189	94
		K0116	Gas Generator Valve Closed P/U	Within 500 ms from K0006	77	76
		K0119	Main Fuel Valve Closed P/U	225 \pm 25 ms from K0118	309	180
K0158	*Mainstage Press. Switch A Depress. P/U			*	167	
K0159	Mainstage Press. Switch B Depress. P/U			*	168	
K0191	Mainstage OK D/O			*	170	
K0007	Helium Control Solenoid Enrg D/O			1,000 \pm 110 ms from K0013	794	

*Signal drops out when pressure reaches 425 \pm 25 psig.

P/U - Pickup

D/O - Dropout

TABLE 6-7 (SHEET 8 OF 8)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (MS)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
SS-22 K0507	PU Activate Switch D/O			DNA	3,055	
		K0125	Oxidizer Turbine Bypass Valve Closed D/O		175	174
		K0124	Oxidizer Turbine Bypass Valve Open P/U	10,000 ms from K0013	852	851
K0126	LOX Bleed Valve Closed D/O			Within 30,000 ms from K0005	9,007	9,006
K0127	LH2 Bleed Valve Closed D/O			Within 30,000 ms from K0005	9,652	9,651

P/U - Pickup

D/O - Dropout

DNA - Data not available

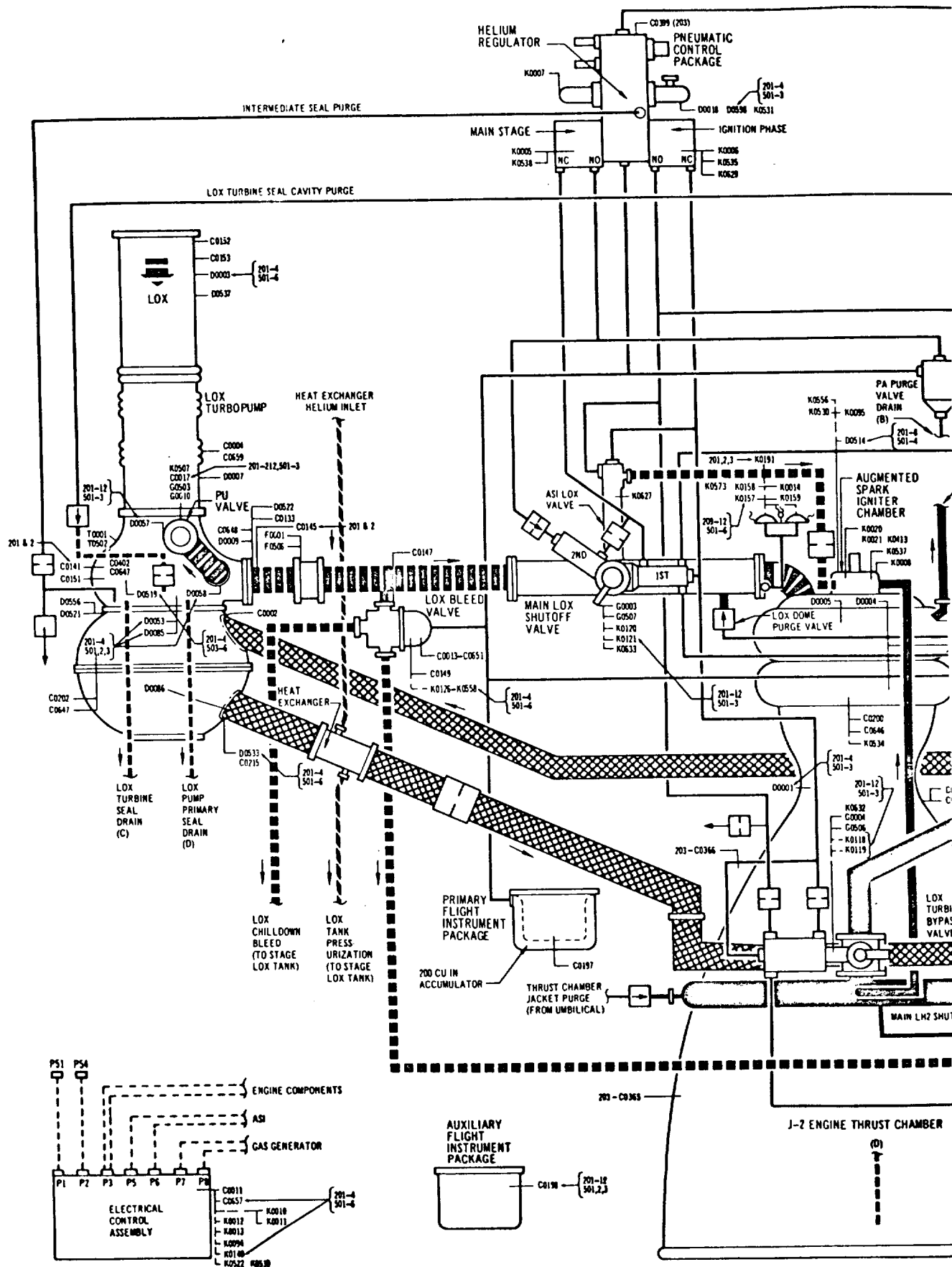
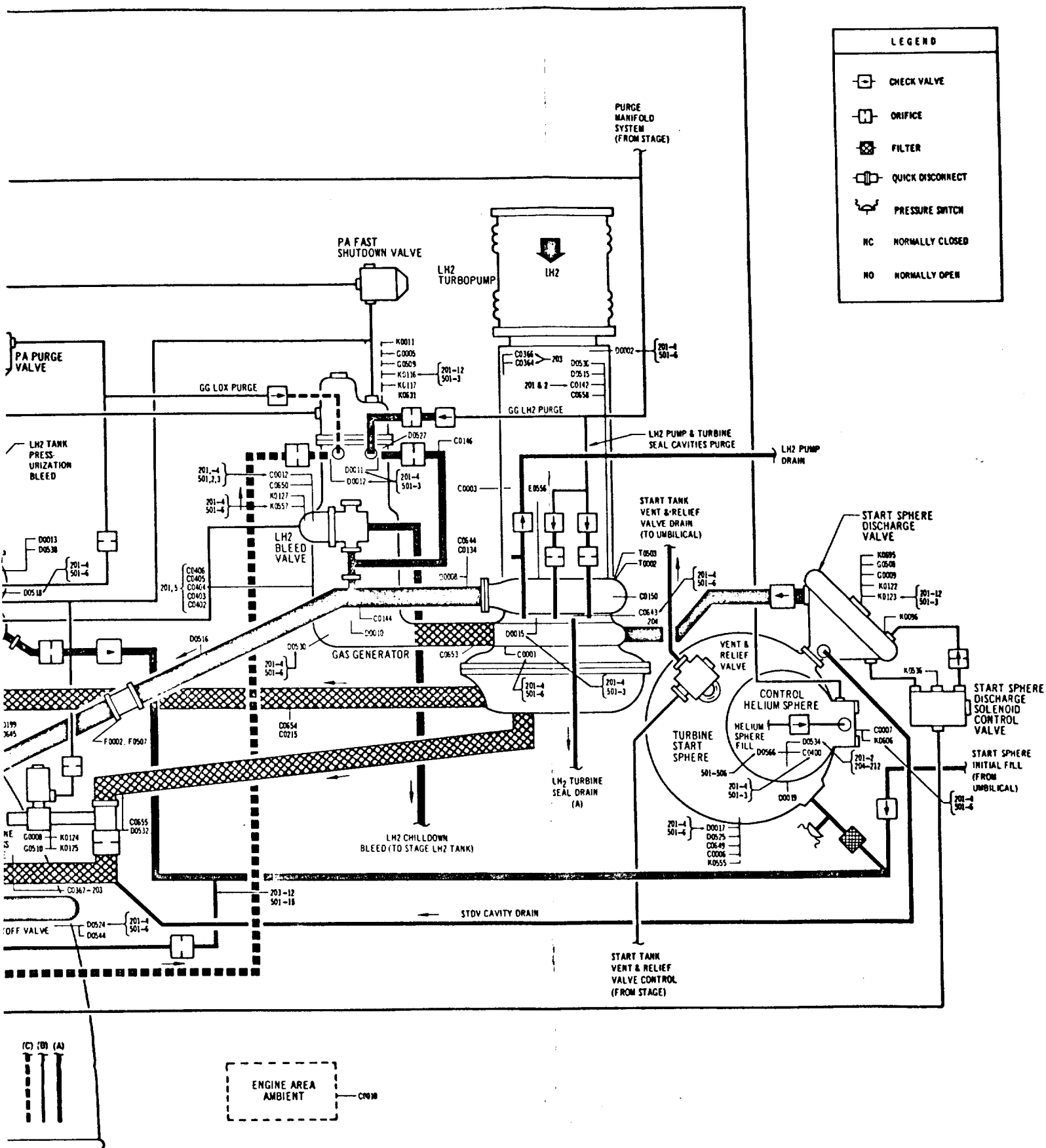


Figure 6-1. J-2



Engine System and Instrumentation

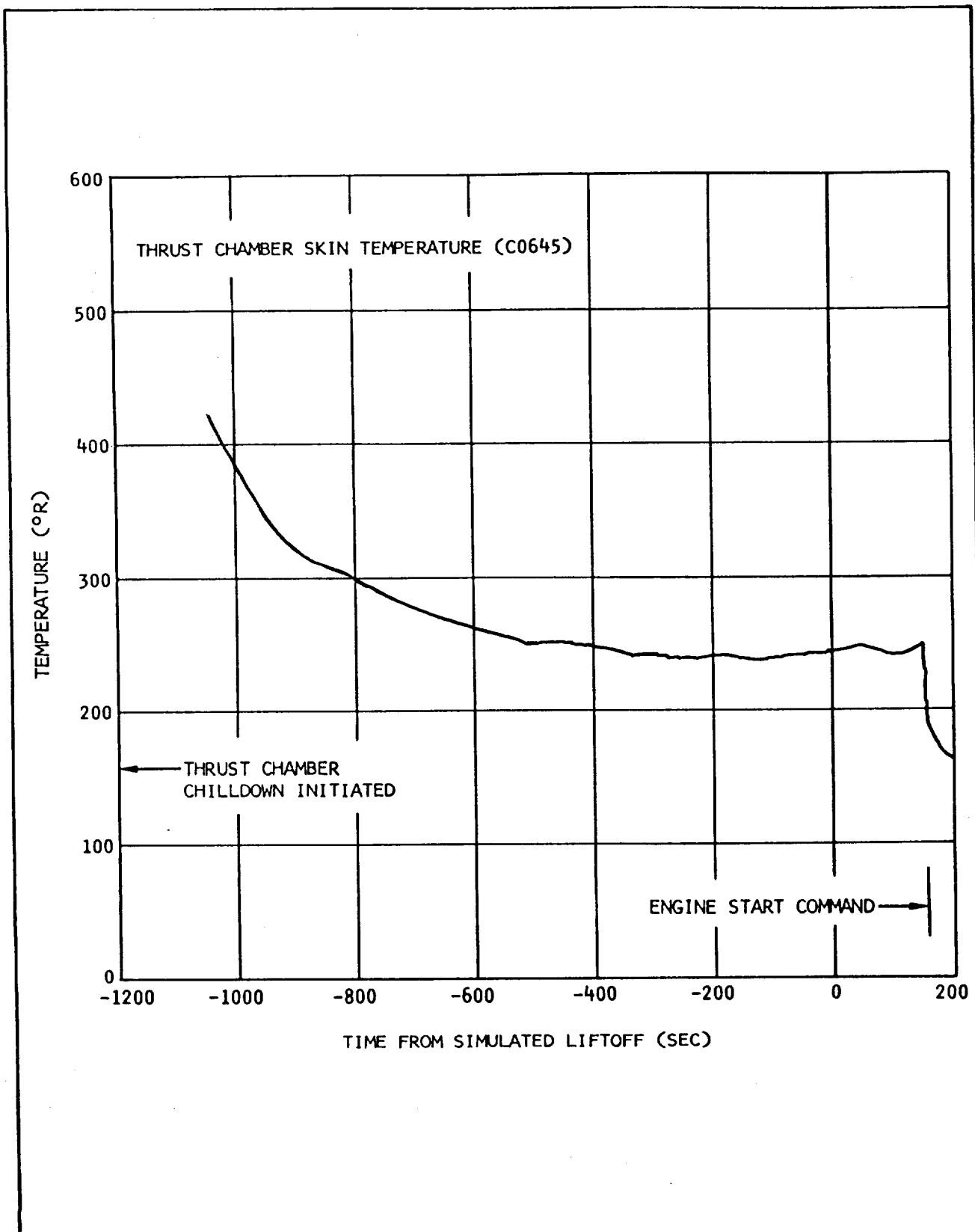


Figure 6-2. Thrust Chamber Chillum

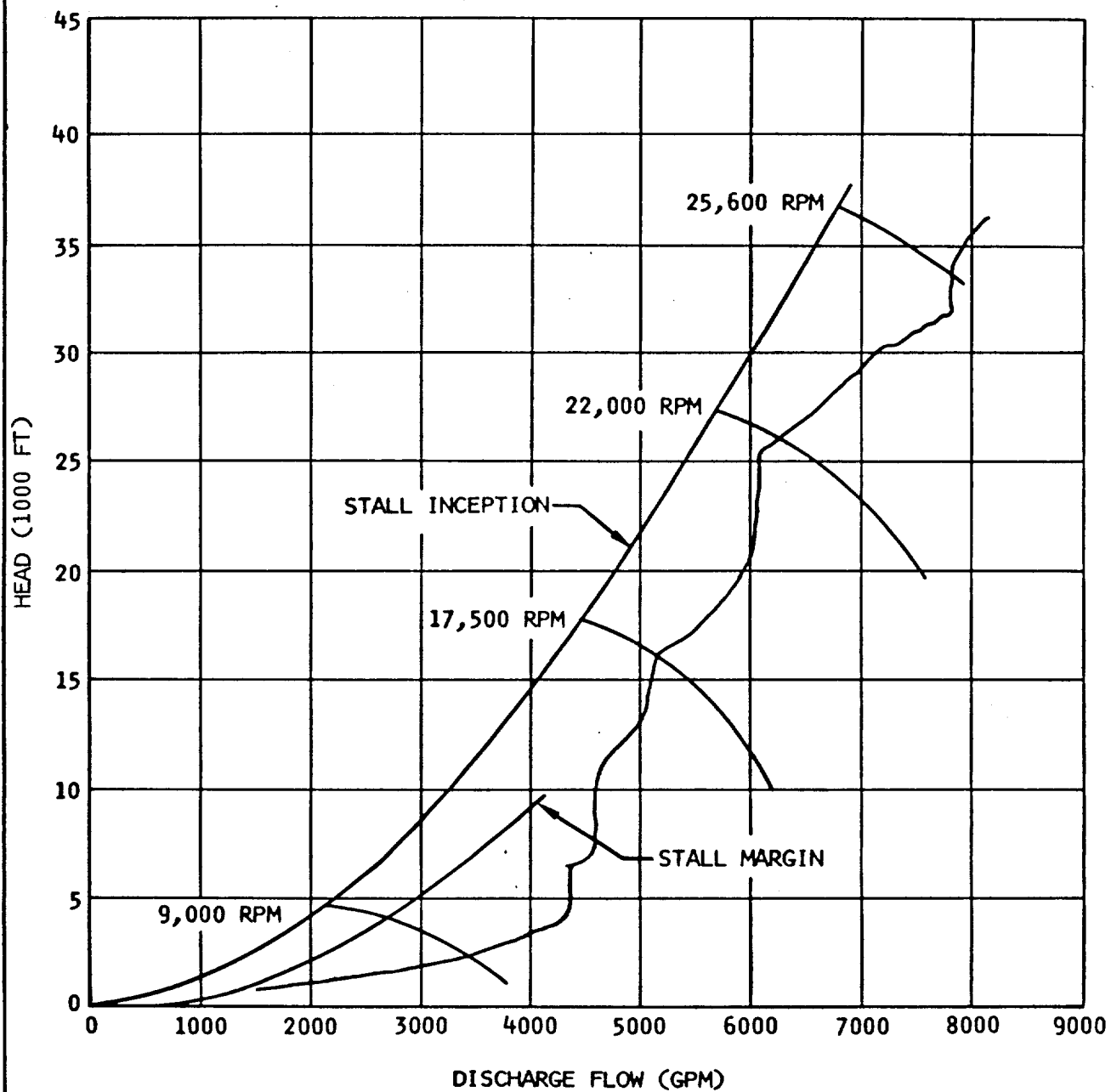


Figure 6-3. LH2 Pump Performance During Engine Start

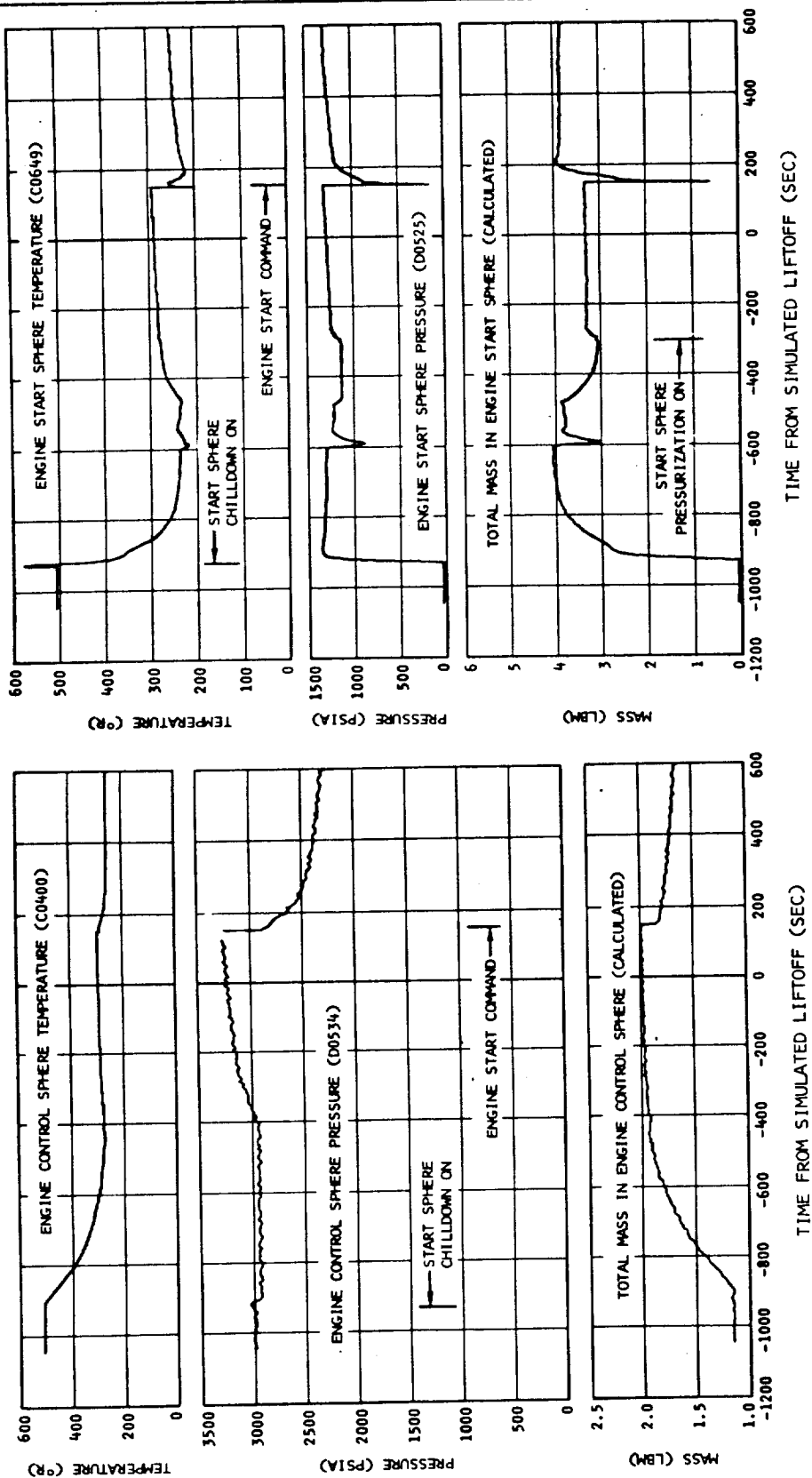


Figure 6-4. Engine Start and Control Sphere Performance

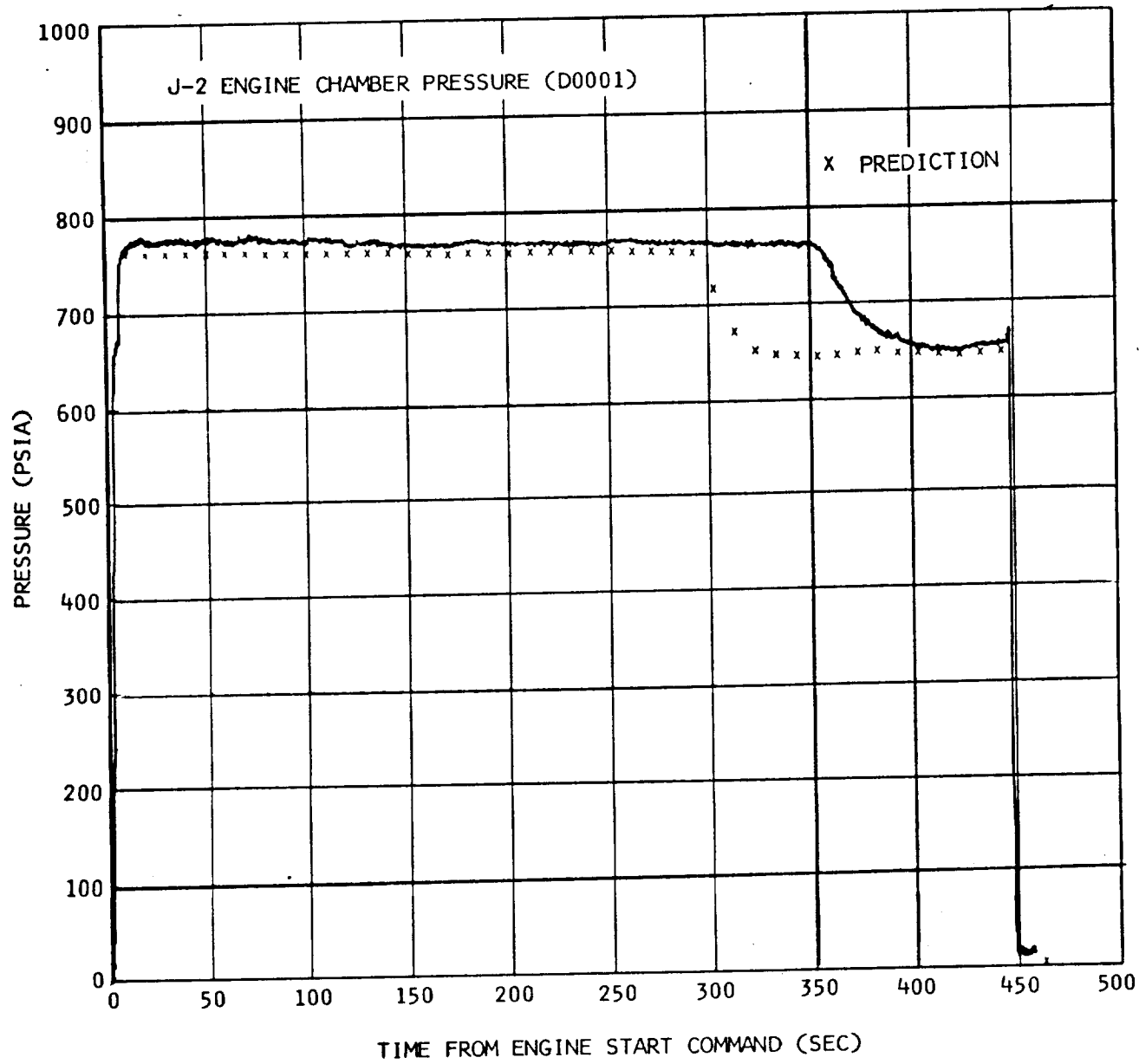


Figure 6-5. J-2 Engine Chamber Pressure

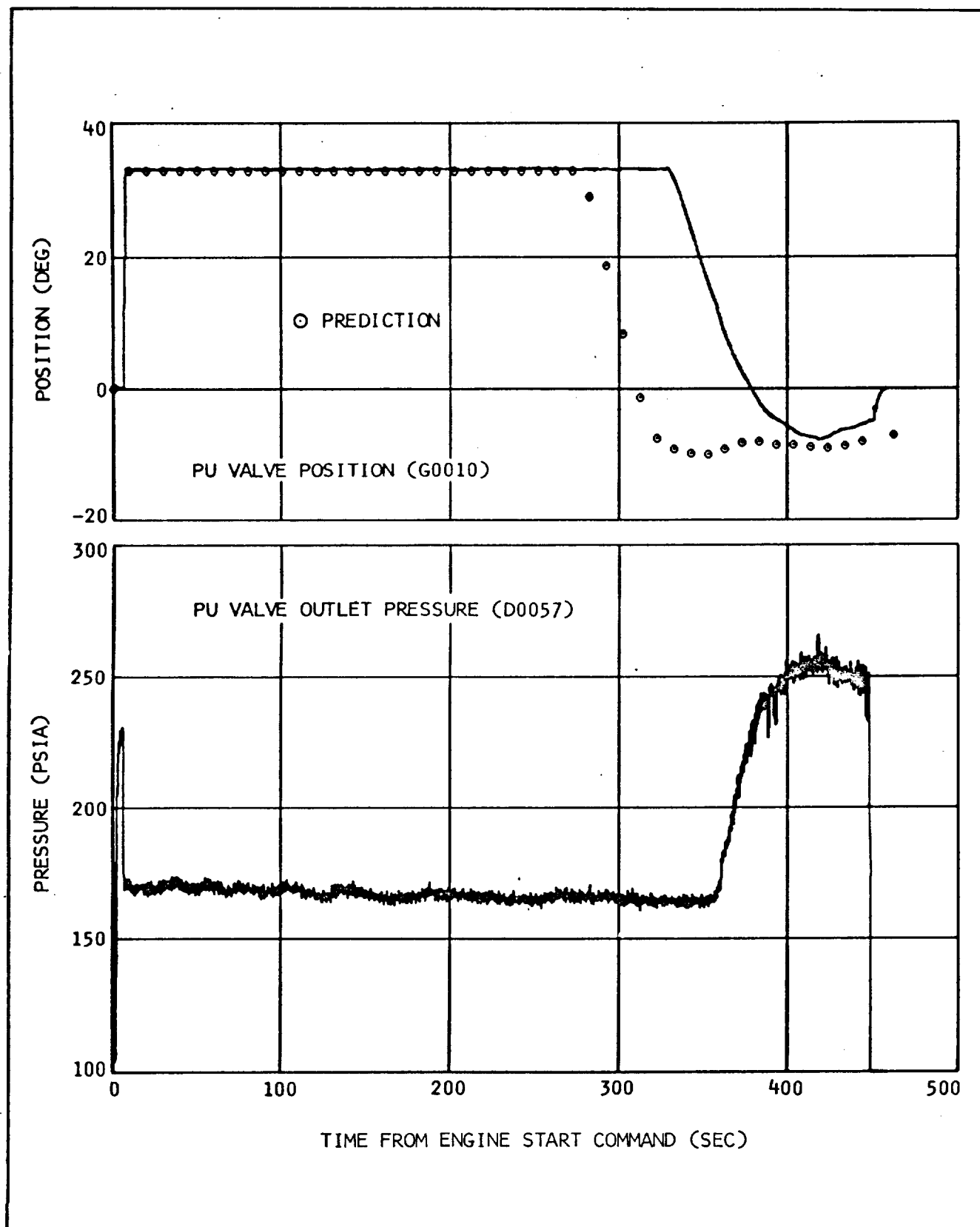


Figure 6-6. PU Valve Operation

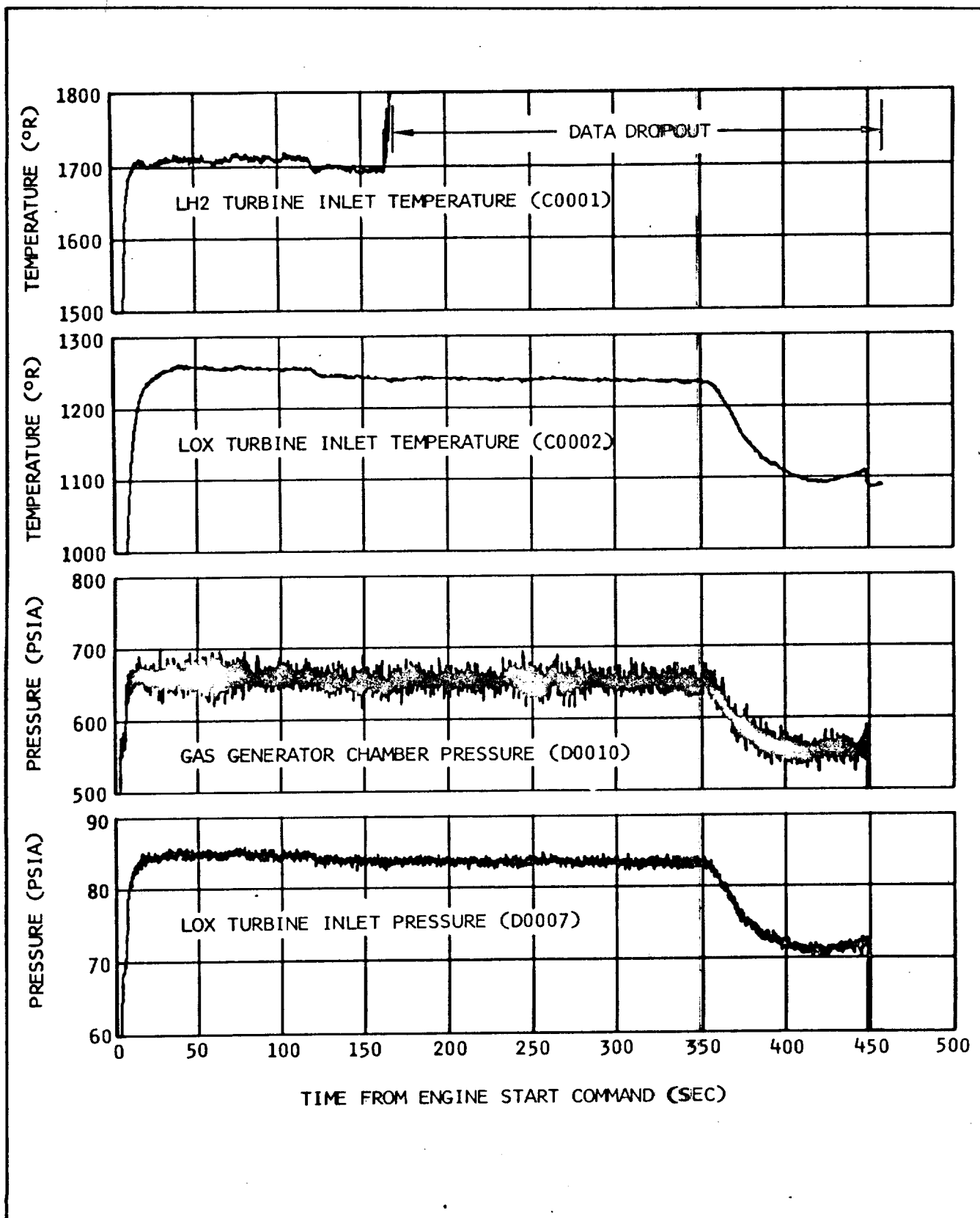


Figure 6-7. Turbine Inlet Operating Conditions

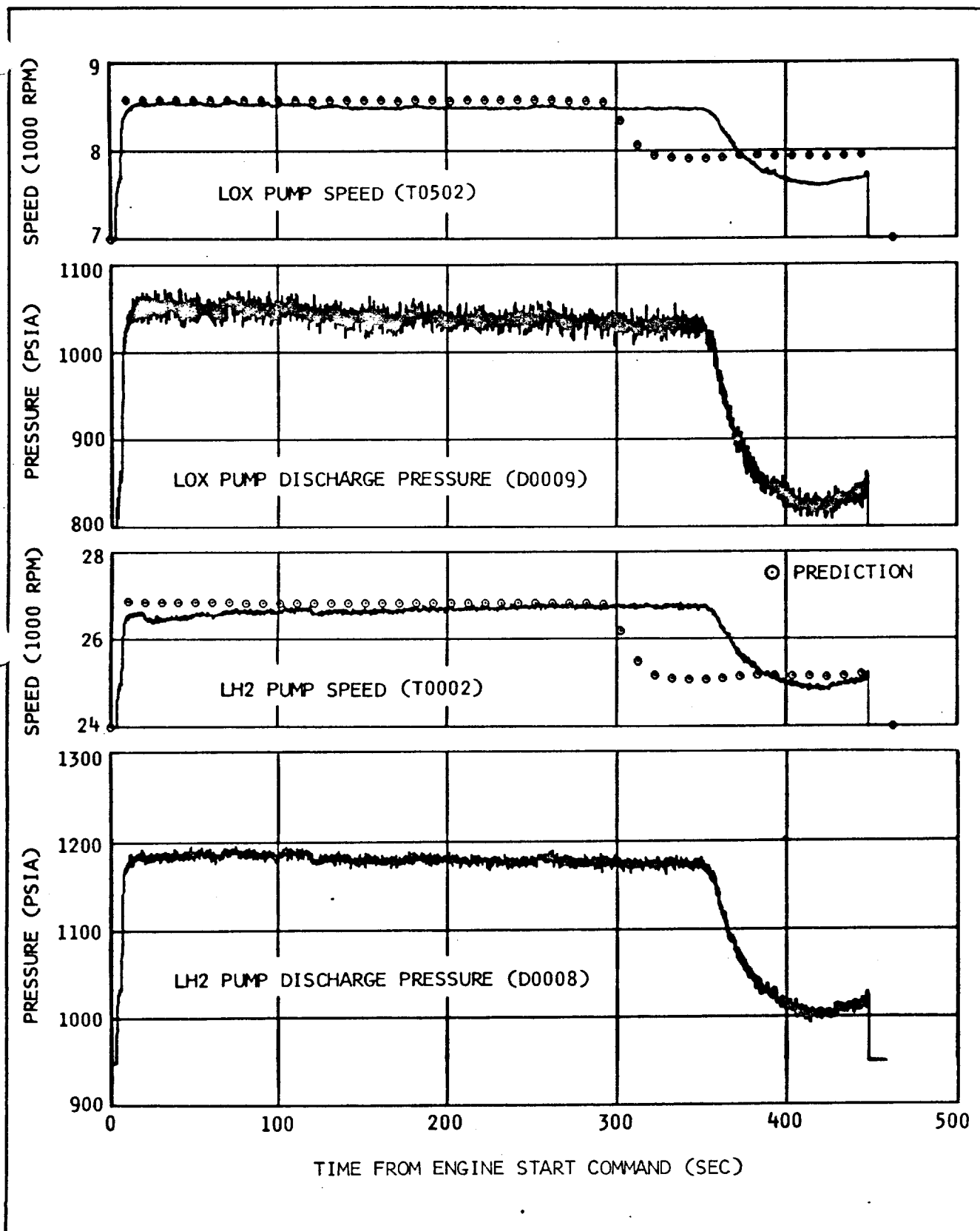


Figure 6-8. J-2 Engine Pump Operating Characteristics

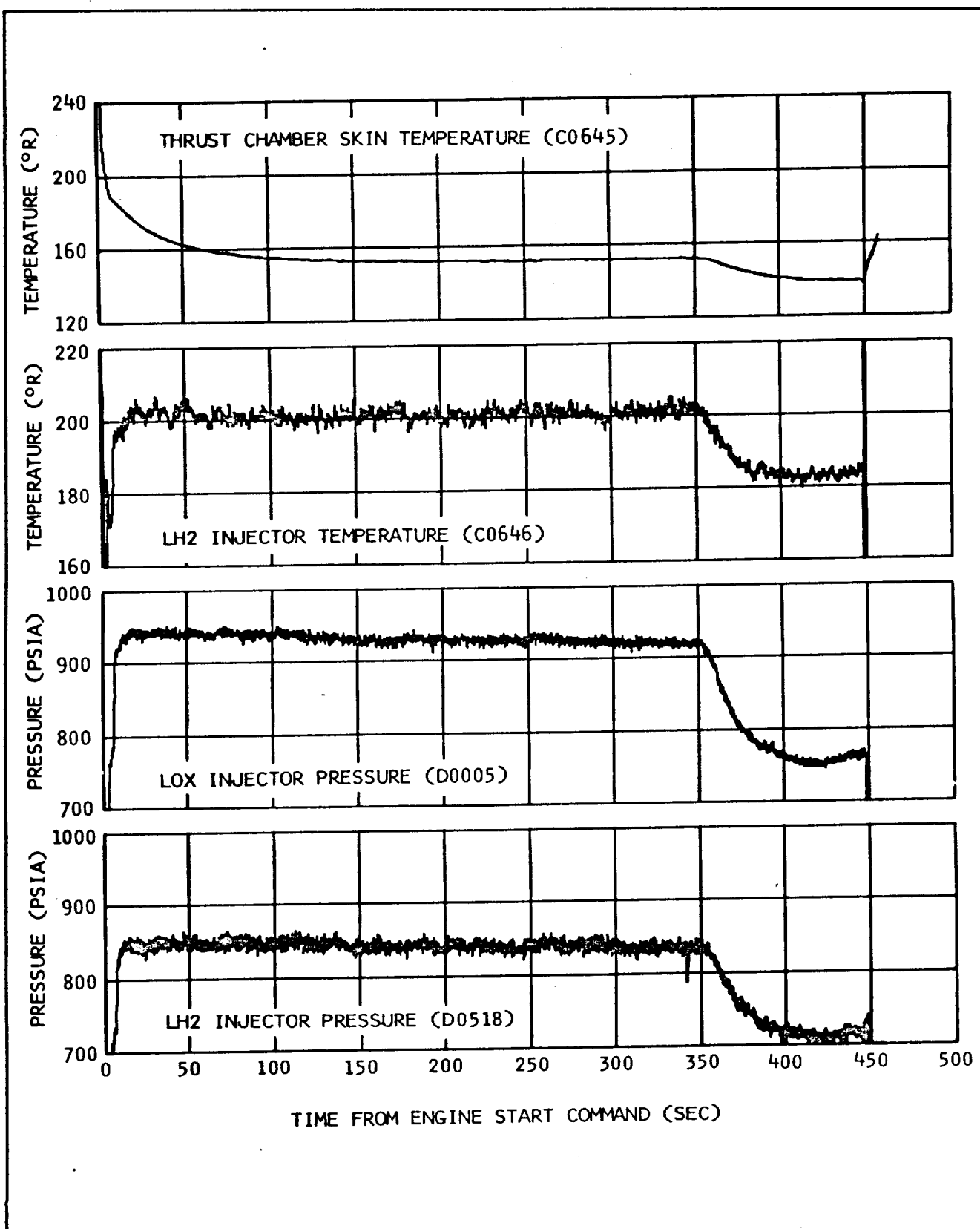


Figure 6-9. J-2 Engine Injector Supply Conditions

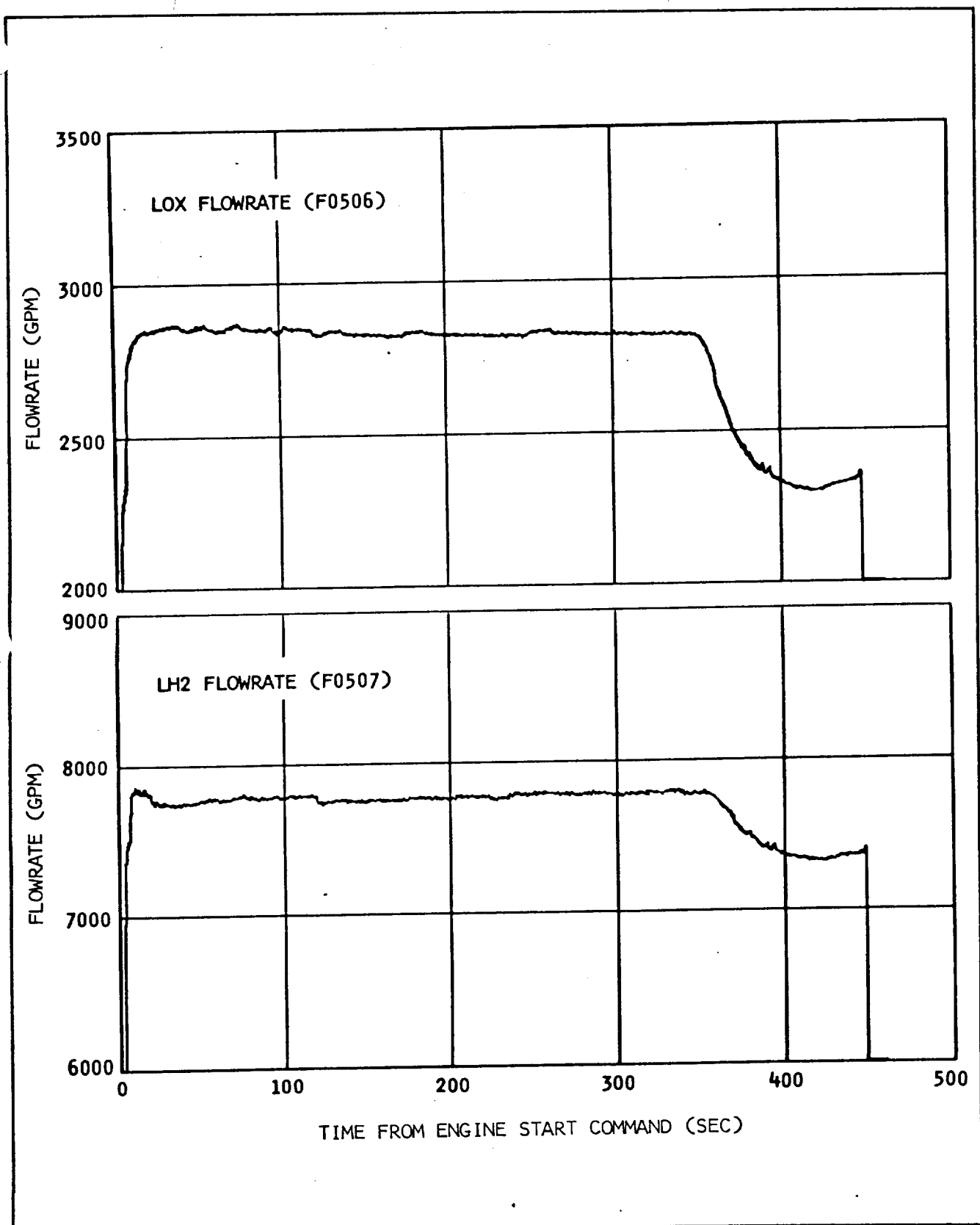


Figure 6-10. LOX and LH2 Flowrate

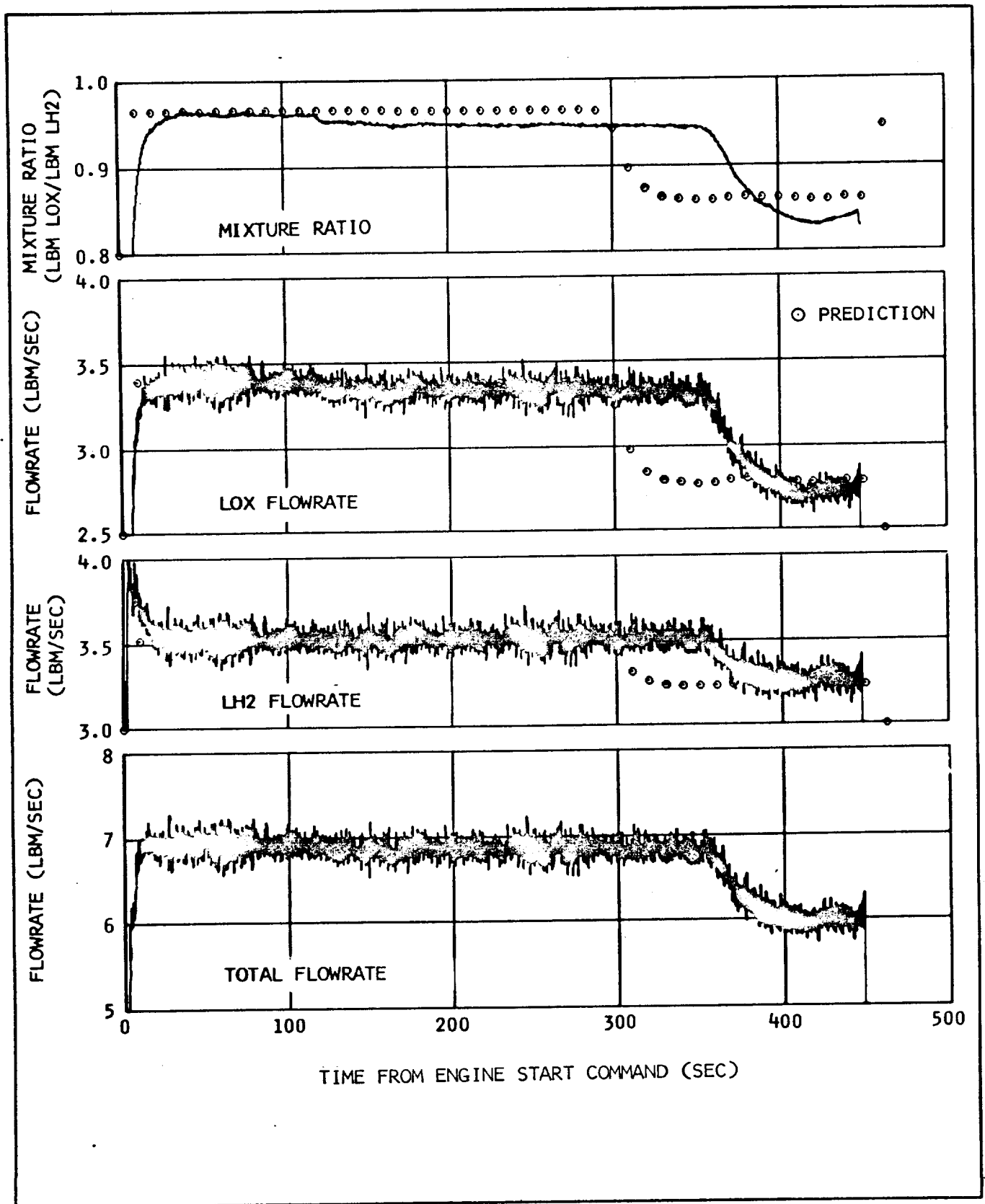


Figure 6-11. Gas Generator Performance

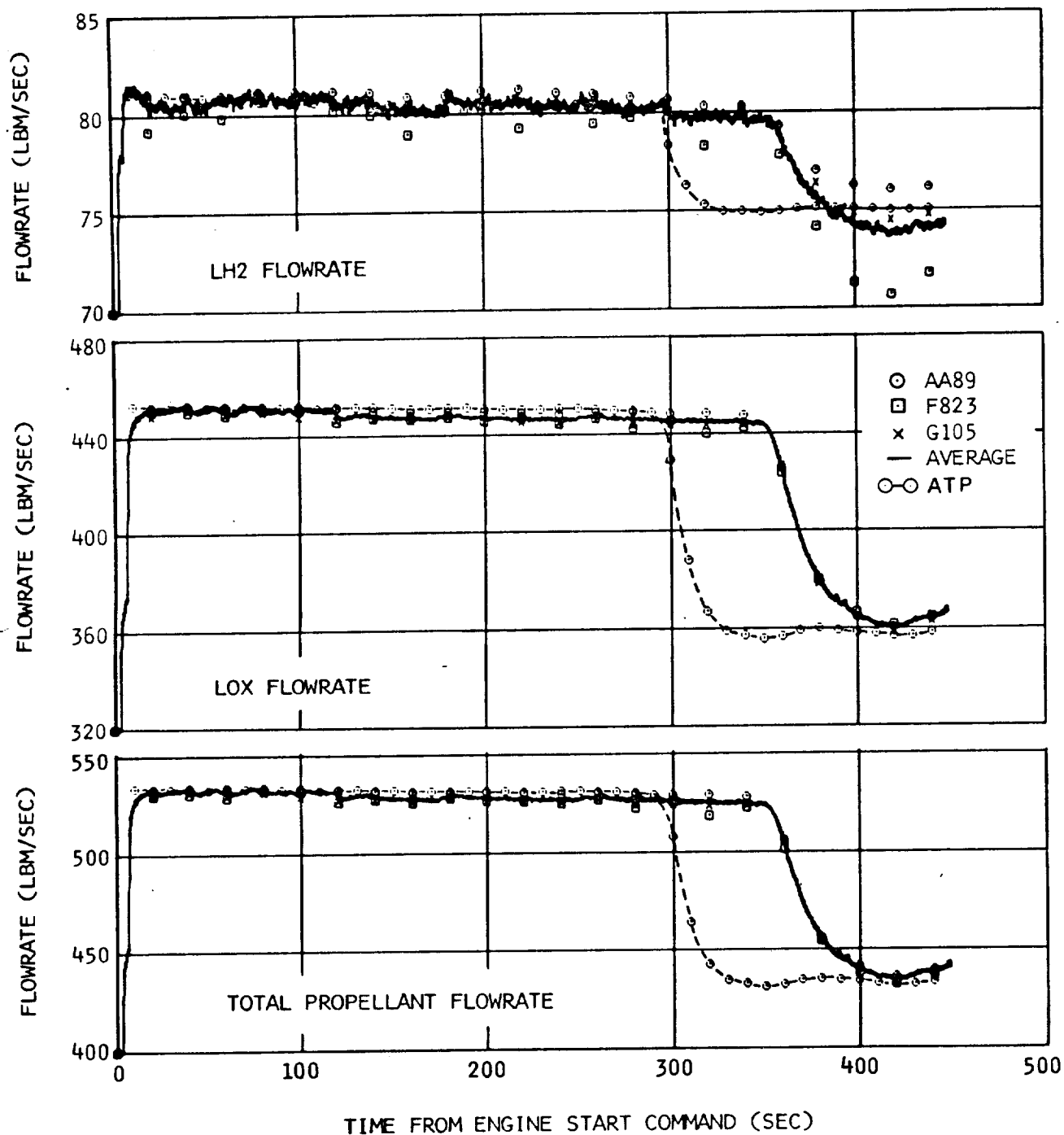


Figure 6-12. Engine Steady-State Performance (Sheet 1 of 2)

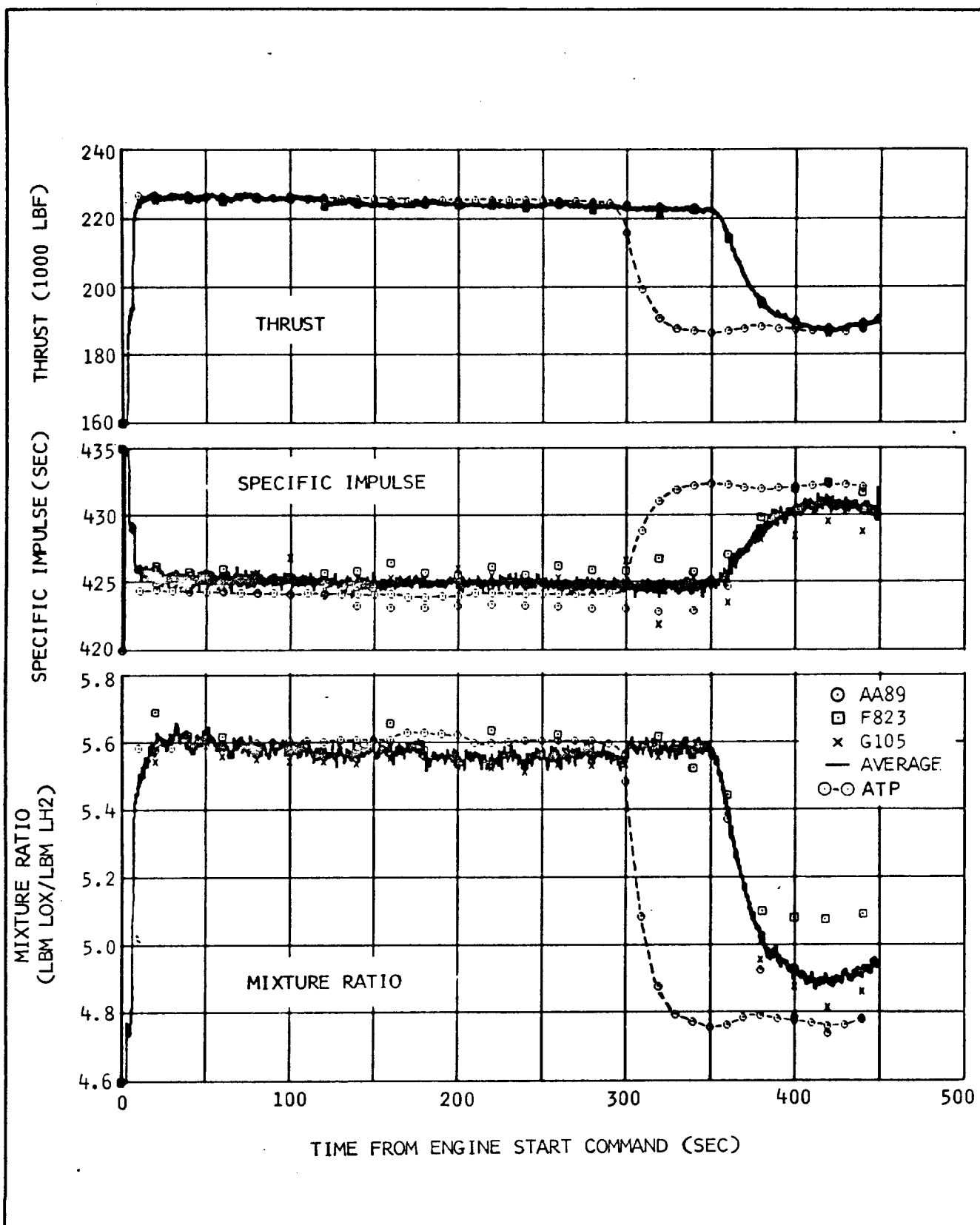


Figure 6-12. Engine Steady-State Performance (Sheet 2 of 2)

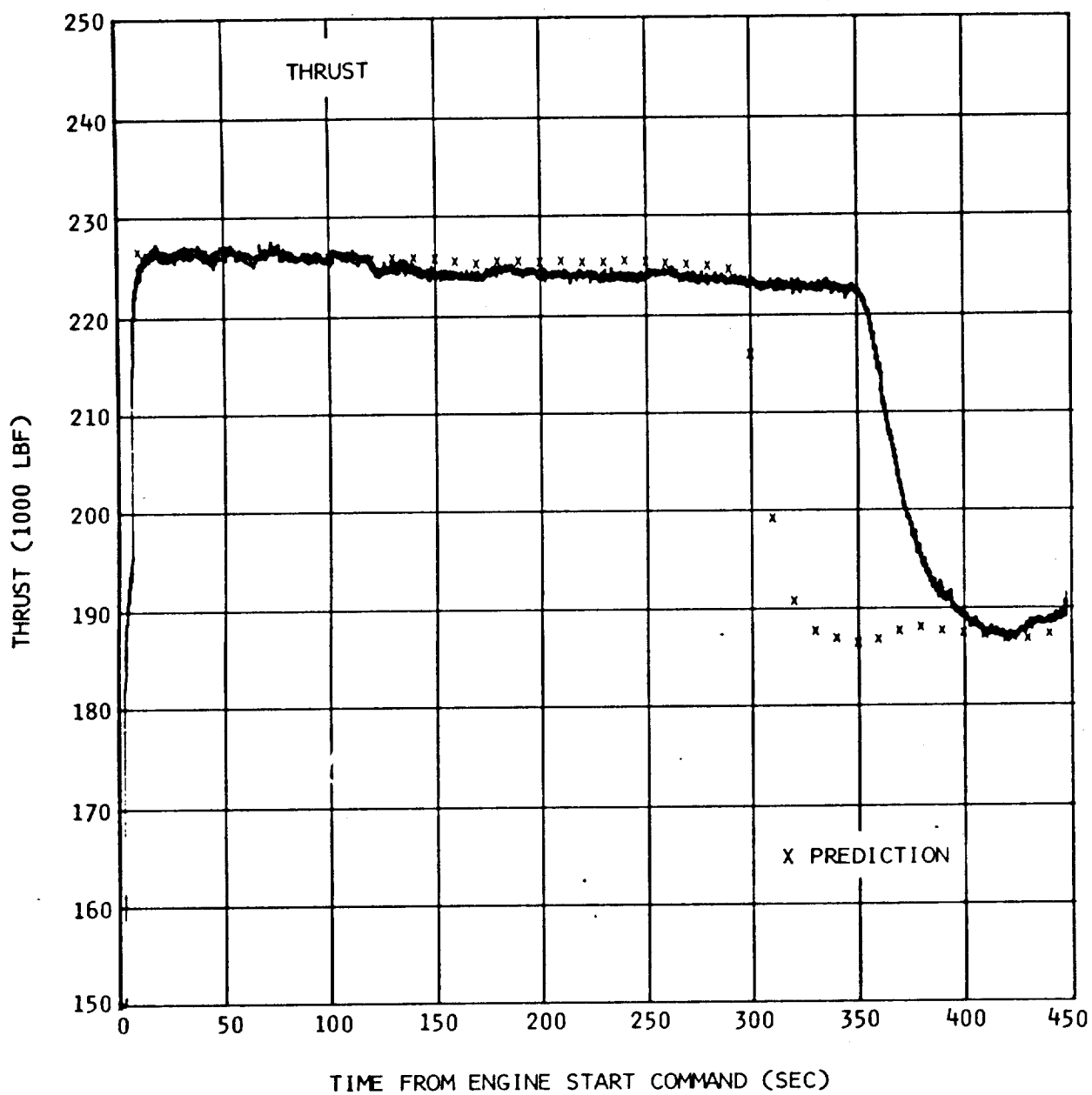


Figure 6-13. J-2 Engine Thrust History

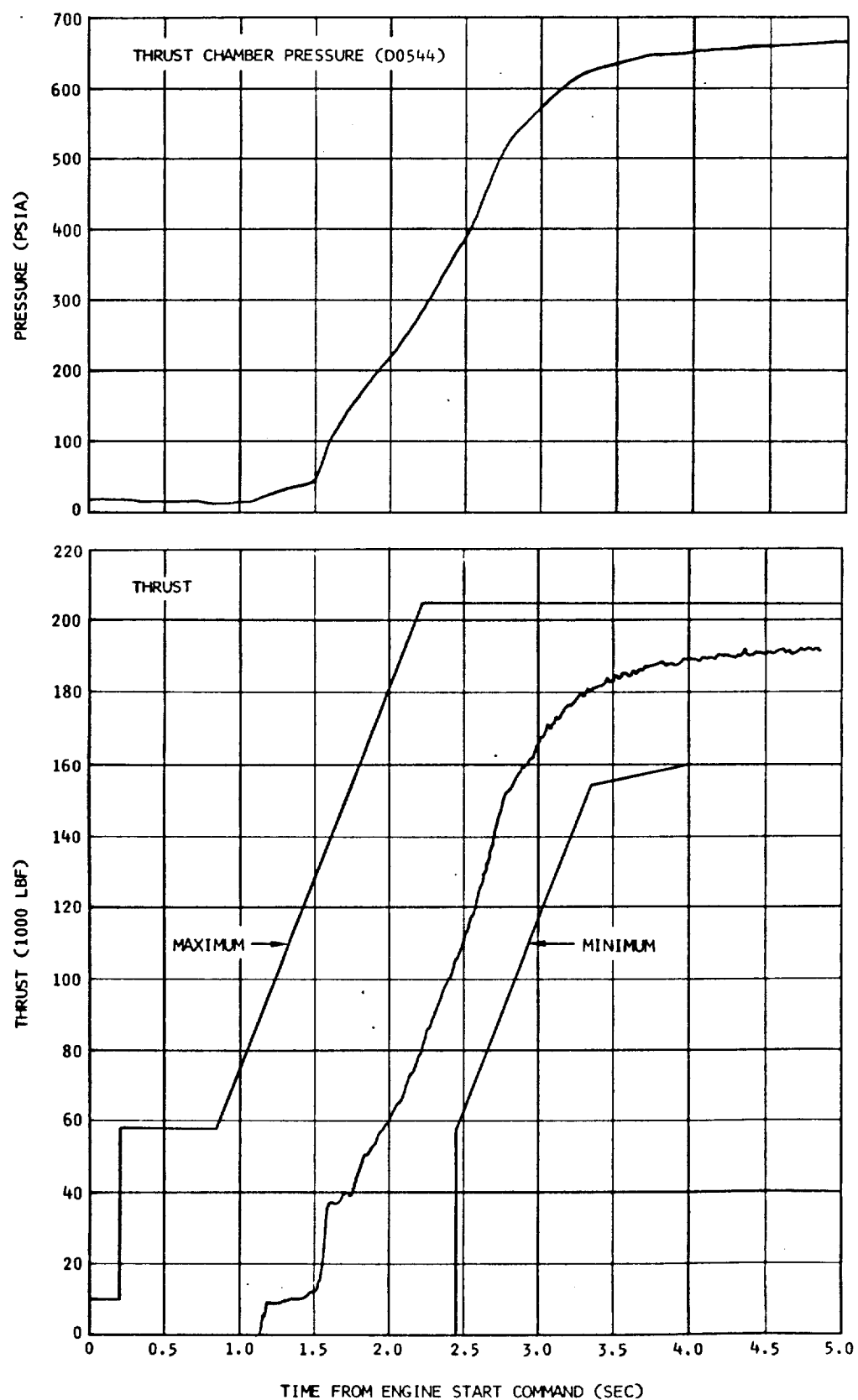


Figure 6-14. Engine Start Transient Characteristics

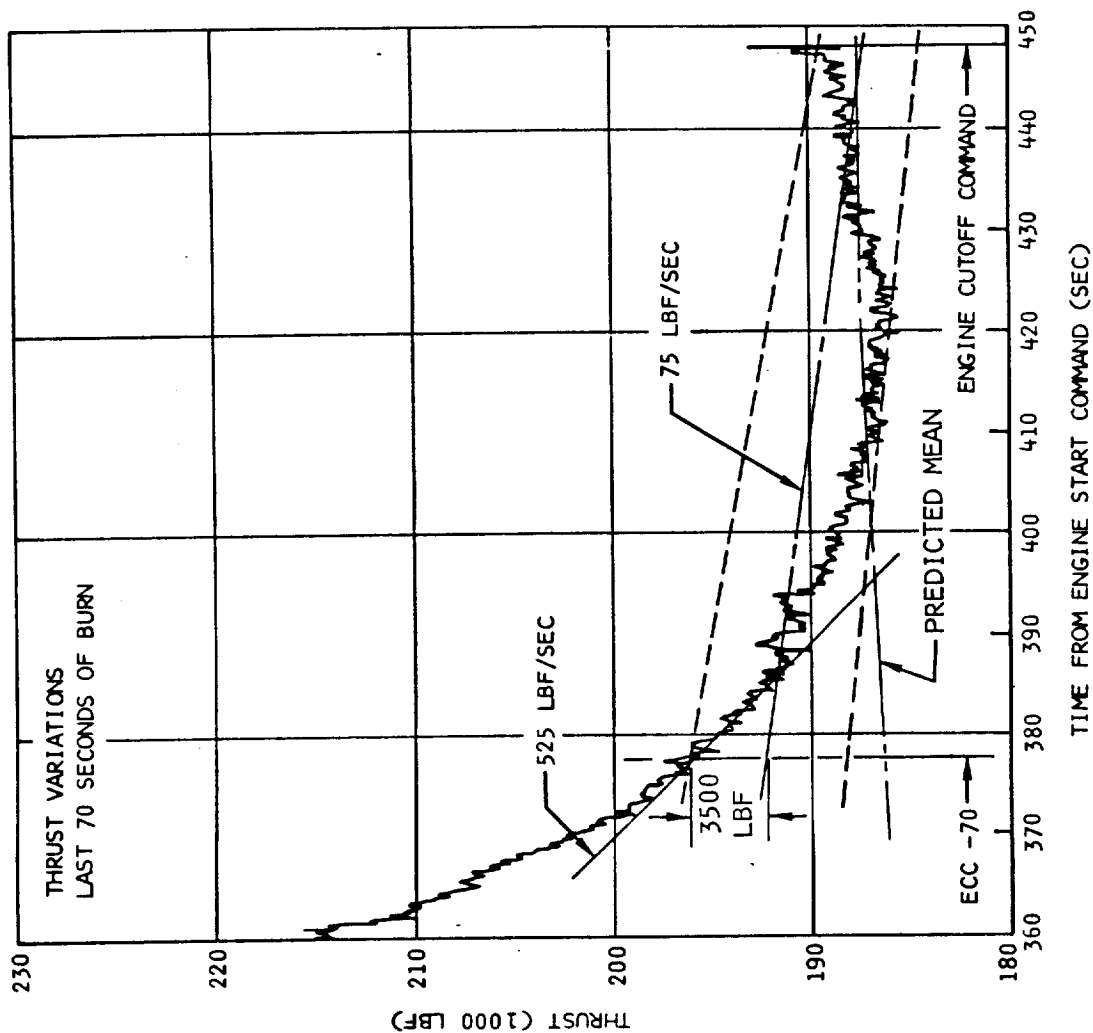
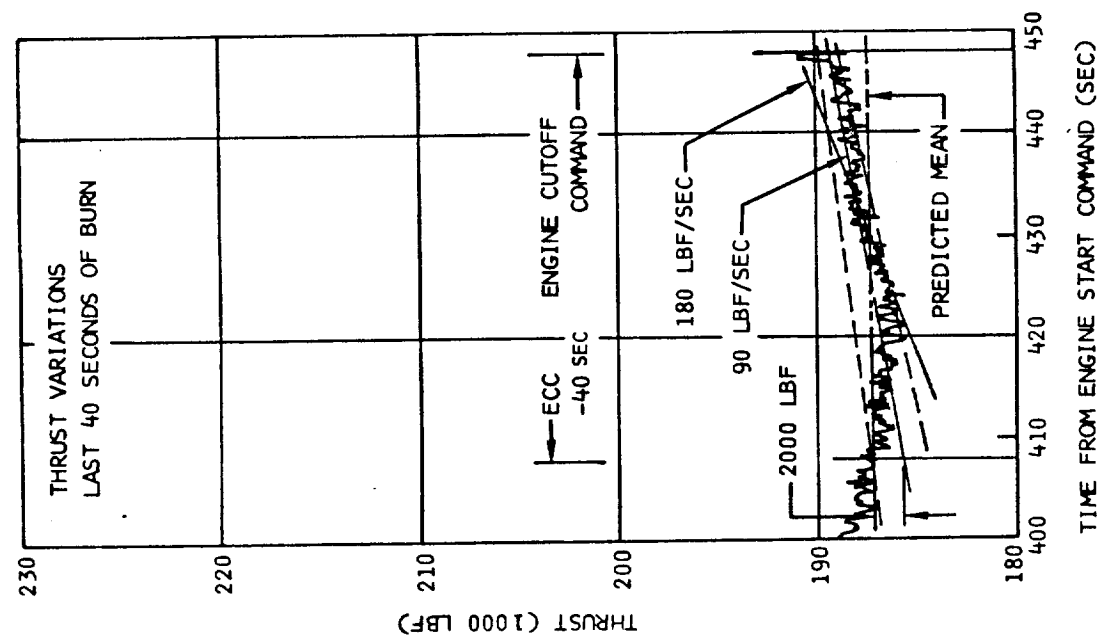


Figure 6-15. Thrust Variations

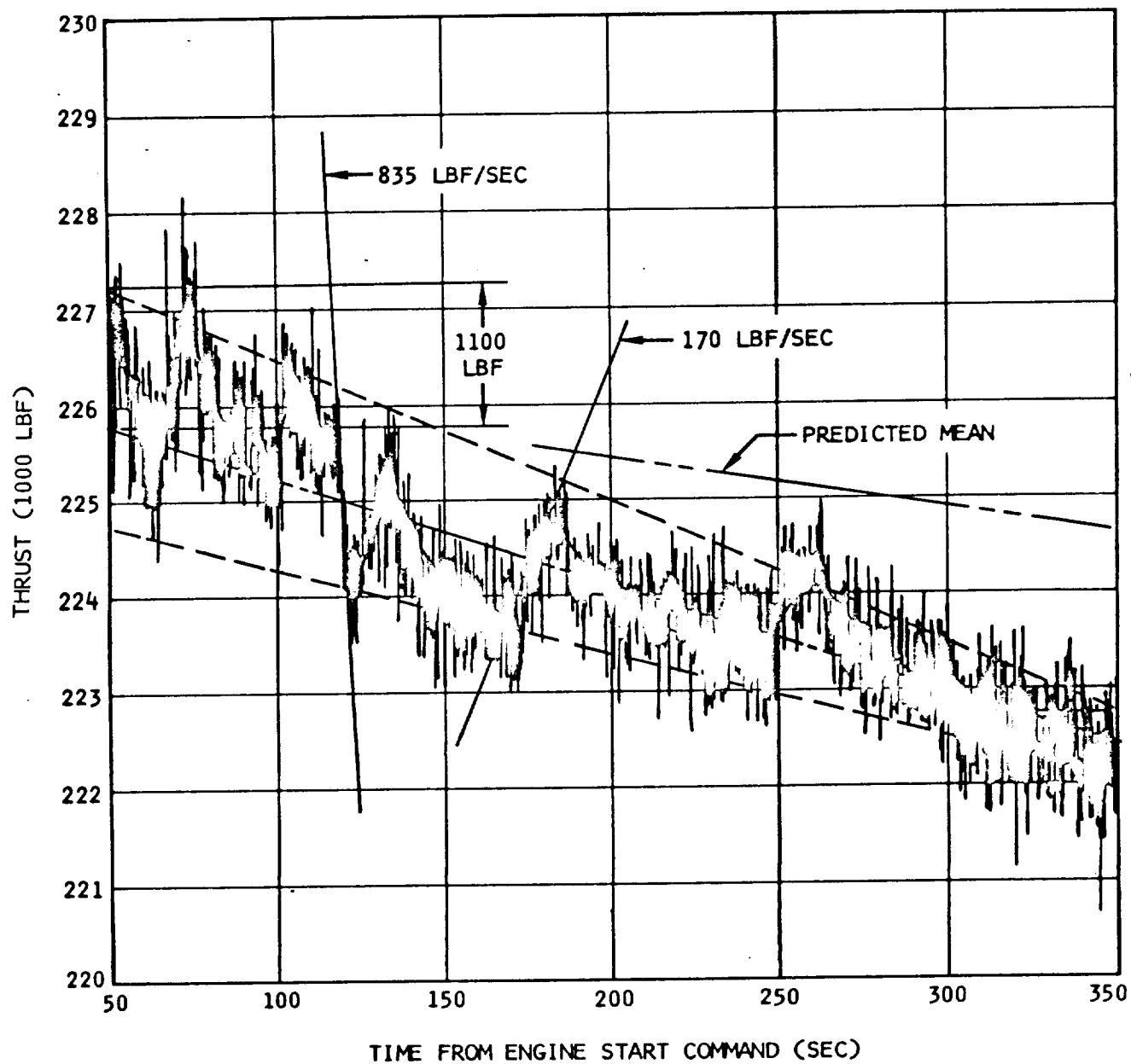


Figure 6-16. Thrust Variations--Hardover (5.5/1.0 EMR)

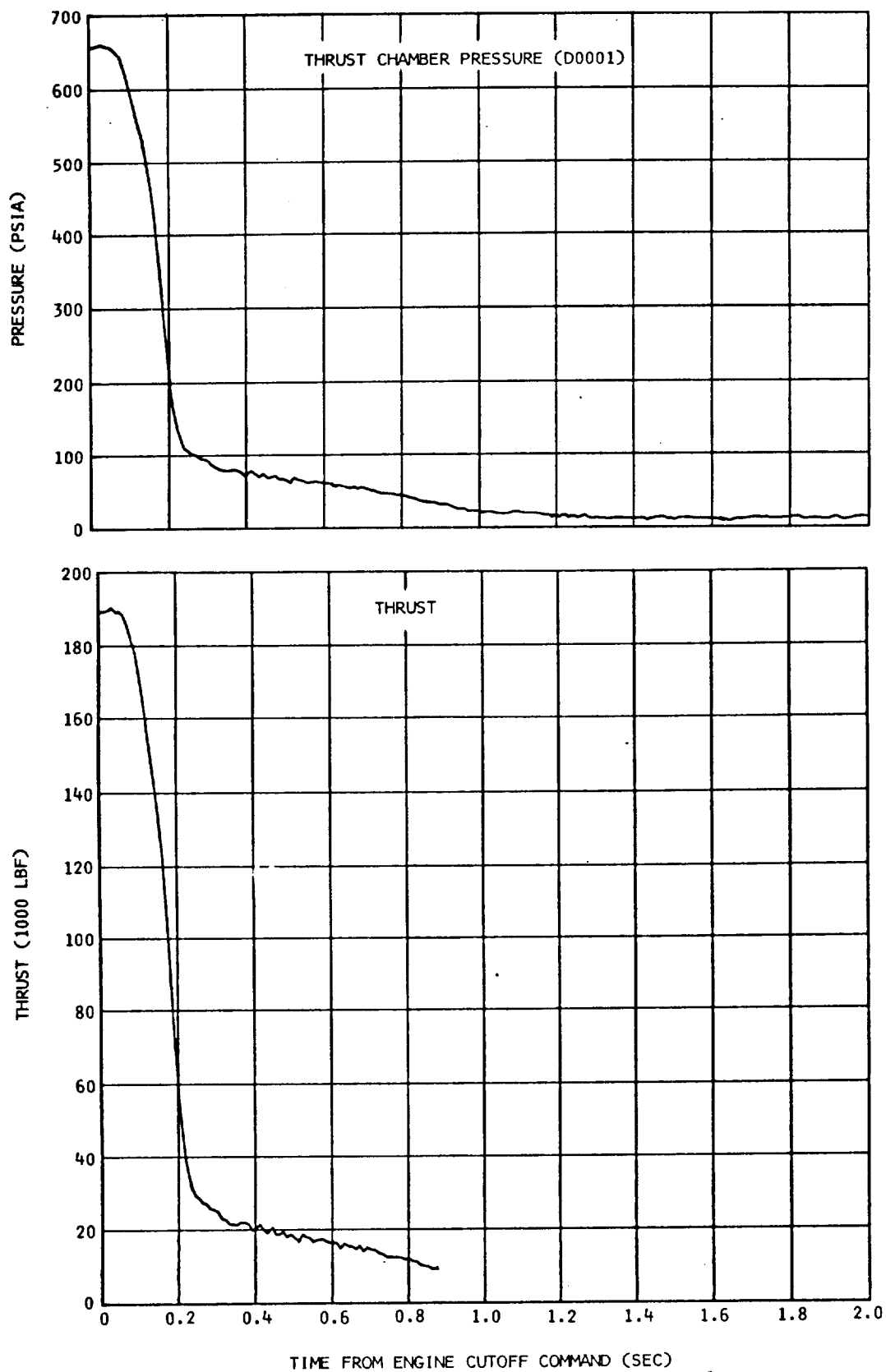


Figure 6-17. Engine Cutoff Transient Characteristics

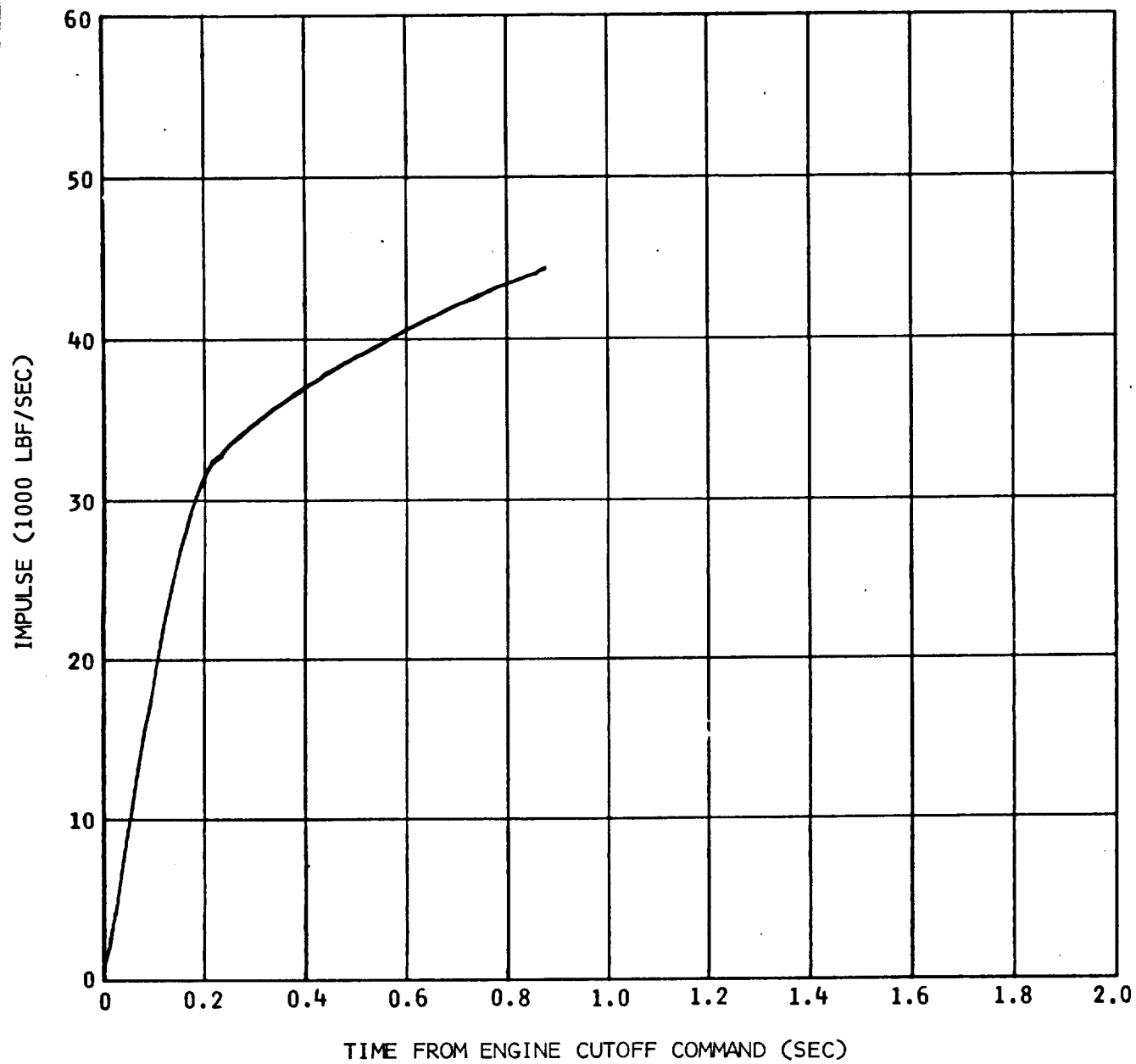


Figure 6-18. Total Accumulated Impulse After Engine Cutoff Command

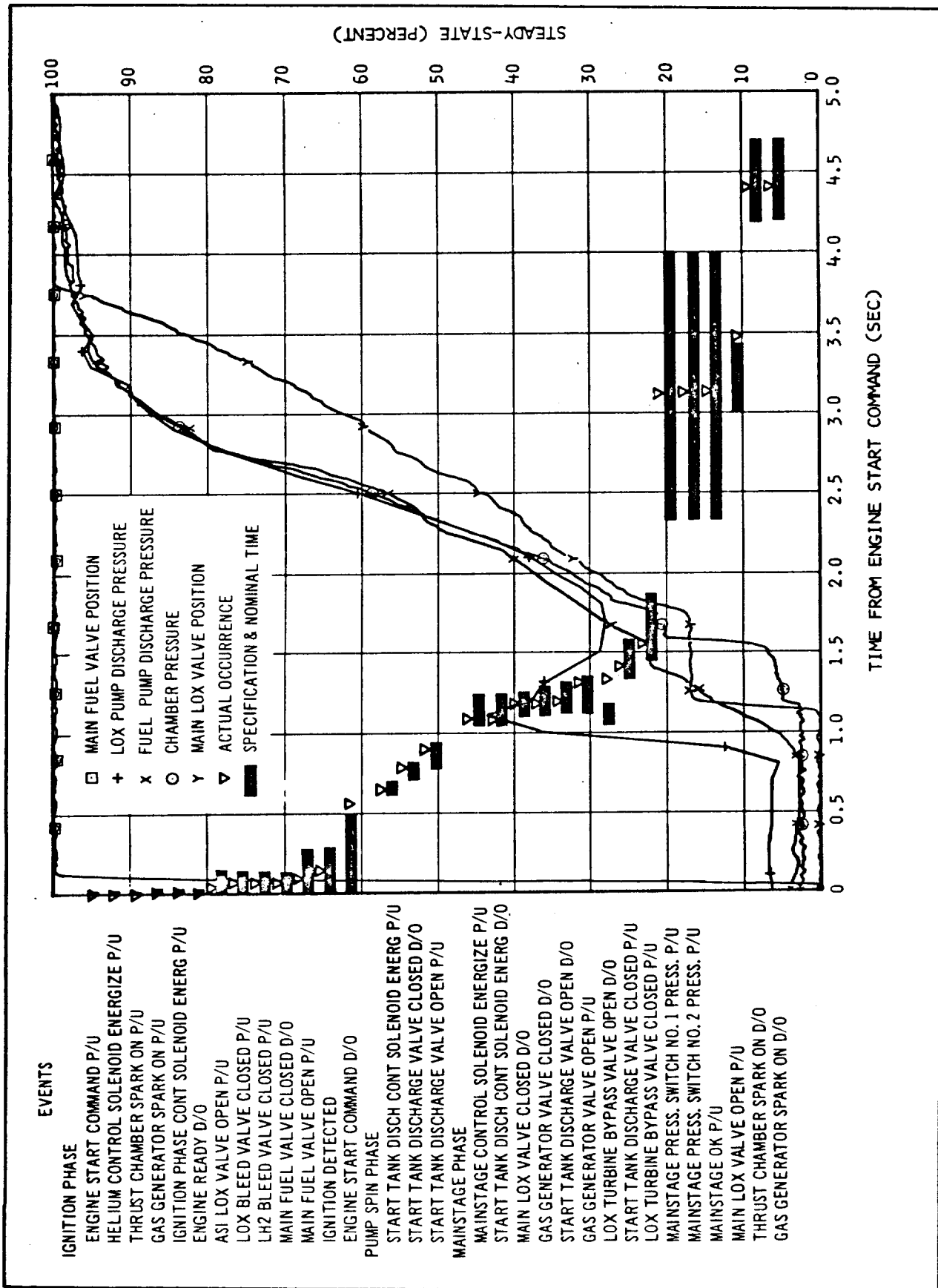


Figure 6-19. Engine Start Sequence

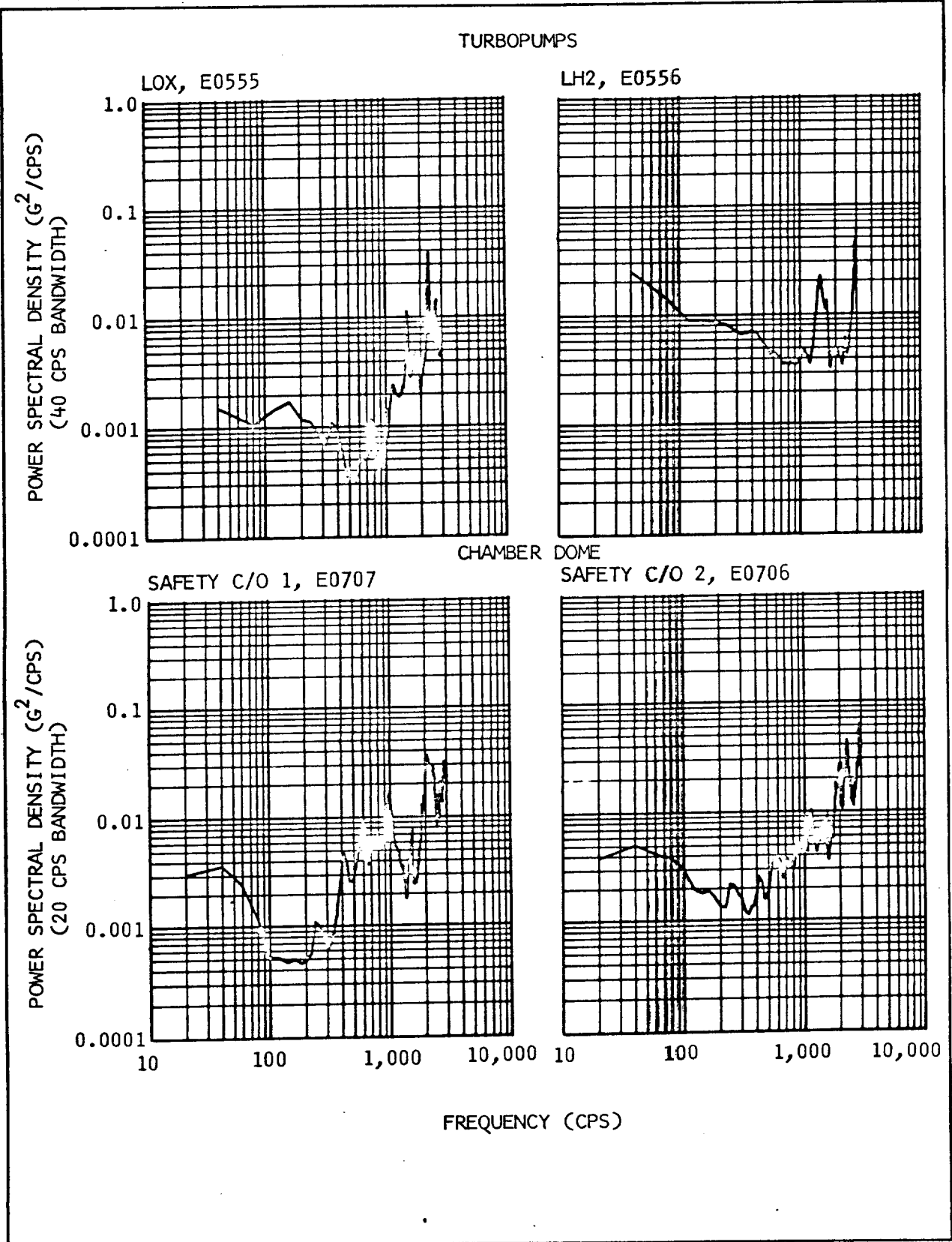
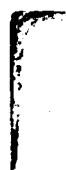
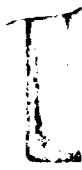


Figure 6-20. Engine Vibration



SECTION 7

OXIDIZER SYSTEM

7. OXIDIZER SYSTEM

The oxidizer system functioned adequately, supplying LOX to the engine pump inlet within the specified operating limits. The net positive suction head (NPSH) available at the LOX pump inlet exceeded the engine manufacturer's minimum requirements at all times.

7.1 Pressurization Control

The LOX tank pressurization system (figure 7-1) satisfactorily maintained pressure in the LOX tank throughout the acceptance firing. All portions of the system performed close to the design requirements.

7.1.1 Prepressurization

LOX tank prepressurization was initiated from GSE console B cold helium supply at ESC -312 sec and increased the LOX tank ullage pressure from ambient to 40.5 psia within 16 sec (figure 7-2). Before the ullage temperature stabilized, one makeup cycle was required to maintain the LOX tank ullage pressure above 37.5 psia. After the makeup cycle, the ullage pressure decreased and then increased normally to the LOX vent relief setting because of the helium purge of the vent valve. Although no relief valve opening was recorded, the relief valve apparently began "feathering" at this time because the ullage pressure indicated that gas was escaping from the tank.

Table 7-1 compares significant LOX tank prepressurization data from several stages.

7.1.2 Pressurization

The operation of the LOX tank pressurization system was nominal during engine firing. At Engine Start Command, the ullage pressure was 41.9 psia. During the start transient, the normal pressure decrease and recovery occurred. As predicted, secondary flow was required seven times to maintain the ullage pressure within the range of 37.4 to 39.45 during the firing.

Table 7-2 compares the S-IVB-207 stage pressurization system data with data from previous acceptance firings.

The LOX tank pressurization module operation was nominal (figure 7-3) and compared well with that of previous stages. The pressurization module plenum chamber pressure (D0105) data were erroneous due to a calibration problem and were corrected by the addition of a +20 psi linear bias to the data. After 270 sec, the corrected data started a slow decrease and reached 398 psia at engine cutoff, which was within the 400 \pm 25 psia requirement. Because the normal increase in pressurization module outlet temperature occurred during the same period, the cold helium flowrate gradually decreased. This flowrate decrease was similar to, but somewhat greater than, that noted on previous stages and probably caused by the greater than usual decrease in module outlet pressure which was still within requirements.

7.2 Cold Helium Supply

At Engine Start Command, the cold helium spheres contained 254 lbm of helium at 2,990 psia and 39.7 deg R. The conditions of the cold helium spheres at significant times are presented in table 7-2. The temperature and pressure profiles were normal and are shown in figure 7-4.

The number of cold helium spheres was reduced from eight to six on the S-IVB-206 and subsequent stages, thereby reducing the helium storage capacity from approximately 350 lbm to 250 lbm. Because of the lesser mass, the sphere pressure at engine cutoff was 500 to 600 psia instead of the previously noted 1,200 to 1,400 psia; however, the pressures at engine cutoff for acceptance firings and those predicted for flights were above the minimum required for required for regulator operation. Calculations indicate that, had another pressure cycle occurred between ESC +250 sec and engine cutoff (as in flights), the final sphere pressure would have been reduced by approximately 35 psia.

After it reached a minimum, the sphere pressure tended to level off, rather than increase as previously noted because of the following conditions:

- a. The pressurant flowrate was larger than it was during previous acceptance firings.
- b. The ullage mixing in the LH2 tank was reduced by the nylon diffuser bag, thereby decreasing the heat transfer to and, therefore, the warmup of the helium spheres as they emerge from the LH2.

7.3 J-2 Heat Exchanger

The J-2 heat exchanger functioned satisfactorily (figure 7-5). The measured LOX vent inlet temperature and the theoretical mixture temperature compared reasonably well with previous acceptance firing data. Significant heat exchanger data are included in table 7-3.

7.4 LOX Pump Chillover

The LOX pump chillover system performance was adequate. At Engine Start Command, the pump inlet conditions of 50 psia and 165.2 deg R were sufficient to produce an NPSH of 33.3 psi which was well above the required value of 16.5 psi.

The pre valve and gas generator bleed valve were open during loading and allowed LOX to enter the system and cool the engine LOX turbopump and the circulation system before the chillover pump was started. Recirculation chillover was started 148 sec before initiation of prepressurization and was terminated shortly before engine start. The pre valve open command was received at ESC -3.98 sec. Dropout of the closed signal occurred 0.62 sec later and was followed by the pickup of the pre valve open signal at ESC -1.73 sec, thus resulting in a delay of 2.26 sec between command and pickup of the pre valve open signal. Bubbles which might have collected under the pre valve during chillover, were removed by opening the pre valve with the chillover pump still running. The chillover shutoff valve was closed immediately before engine start.

The pump inlet pressure followed the ullage pressure during chilldown until the pre valve was opened (figure 7-6). A loss of most of the chilldown pump developed head resulted from opening the pre valve, thus producing a subsequent decrease in pump inlet pressure.

The chilldown system fluid temperatures decreased during the initial minute of chilldown, after which they remained relatively constant until prepressurization. After prepressurization, the temperatures increased because of bulk heating (figure 7-6).

During the chilldown process, the LOX was subcooled throughout the recirculation system. The chilldown flowrate and frictional pressure drop were respectively 36.7 gpm and 8.7 psi prior to prepressurization. Afterwards, the flowrate increased to 41 gpm with a pressure drop of 10.0 psi through the system. The flow coefficient, a measure of the flow resistance, was calculated from the above flowrate and pressure drop data and was found to average $15.3 \text{ sec}^2/\text{in}^2\text{-ft}^3$ during pressurized chilldown (figure 7-7). This value is within the range of the coefficients of previous S-IVB/IB and S-IVB/V stages and indicates equivalent flow resistances for the chilldown systems.

When the chilldown pump was started, the NPSH at the turbopump inlet increased from 6 to 14 psi, then remained constant until prepressurization occurred at SLO -160 sec. It then increased to 41.4 psi and varied directly with the ullage pressure until the pre valve was opened, when it dropped from 41.9 to 33.3 psi as a result of the decrease in pump inlet pressure.

Flowrate and temperature data were used to compute the heat input for sections 1, 2, and 3. These rates decreased rapidly during the first minute of chilldown, then became relatively stable during the subsequent chilldown process (figure 7-7).

A 1-deg peak-to-peak noise level on the bleed valve temperature measurement (C0651) may have been responsible for the relatively high heat input to section 2 and the nearly zero heat input to section 3. If the average of C0651 were decreased by 0.5 deg R (which is well within the

accuracy of the temperature data), the heat input rates would compare favorably with those previously noted. During steady state pressurized chilldown, the heat input rates were as follows:

<u>Section</u>	<u>Calculated</u>	<u>Heat Input Rate (Btu/hr)</u>	
		<u>C0651 With -0.3 deg Bias</u>	<u>Average of S-IVB 204, 205, 206</u>
1 (tank to turbopump inlet)	2,000	2,000	4,170
2 (pump inlet to bleed valve)	17,000	14,000	13,000
3 (bleed valve to tank inlet)	0	2,800	2,330
Total	19,000	19,000	19,300

7.5 Engine LOX Supply

The LOX supply system (figure 7-8) delivered the necessary quantity of LOX to the engine pump inlet throughout the engine firing and maintained the pressure and temperature conditions within a range that provided a LOX pump NPSH above the minimum requirement of 21.0 psi at high EMR and 14.9 psi after EMR cutback. The minimum available NPSH at engine cutoff was 21.8 psi. During engine operation, the LOX pump inlet pressure and temperature were very near predicted. The LOX pump inlet pressure was 50 psia at Engine Start Command and decreased to 40.2 psia during the first 15 sec of engine operation. It then cycled with ullage pressure while generally decreasing with time as the LOX in the tank was consumed and the liquid head decreased.

The LOX temperature at the pump inlet was 164.6 deg R after the start transient and increased with bulk heating to a maximum of 167.5 deg R at engine cutoff (figure 7-9).

The NPSH available at the LOX pump inlet was 33.2 psi at engine start and decreased to 26.0 psi during the first 15 sec of engine operation because of decreasing ullage pressure. The NPSH then cycled with the ullage pressure while generally decreasing with time because of the decreasing liquid head and increasing bulk temperature. By engine cutoff, the NPSH had decreased to a minimum value of 21.8 psi which was well above the allowable minimum of 15.0 psi. The average frictional pressure drop in the LOX suction duct at high EMR was calculated to be 1 to 1.4 psi at a flowrate of approximately 450 lbm/sec. After EMR cut-back the pressure drop averaged 0.4 psi at a flowrate of approximately 368 lbm/sec. These pressure drops were less than the range of values calculated from previous acceptance firings, but were within data accuracy.

The LOX pump inlet pressure and temperature were plotted in the engine LOX pump operating region (figure 7-10) and showed that the engine LOX pump inlet conditions were met satisfactorily throughout engine operation.

In figure 7-11, the pump inlet temperature is plotted against the mass remaining in the LOX tank during engine operation and is compared to the S-IVB-205 and -206 acceptance firing data. The S-IVB-205 and -206 data were shifted so that the initial steady-state temperature of the S-IVB-207 stage acceptance firing and the S-IVB-205 and -206 acceptance firing data agree. (This corrected for instrument error, different heating during prepressurization, and other test-to-test variations.) After this correction was made, it was apparent that the S-IVB-207 temperature was within 0.25 deg of the comparative data, indicating that the heat transfer to the LH2 was very similar to that previously noted.

TABLE 7-1
LOX TANK PREPRESSURIZATION DATA

PARAMETER	S-IVB-205	S-IVB-206	S-IVB-207
Prepressurization initiation (sec from ESC)	-312	-312	-311
Prepressurization duration (sec)	19	13	16
Number of makeup cycles	2	1	1
Prepressurization flowrate (lbm/sec)	0.22 to 0.34	0.25 to 0.35	0.22 to 0.32
Helium added to LOX during main prepressurization (lbm)	5.55	3.3	4.00
Helium added to LOX tank during makeup cycles (lbm)	1.15	1.9	0.66
Ullage pressure at prepres- surization initiation (psia)	14.7	14.7	15.2
Ullage pressure at prepres- surization termination (psia)	39.2	40.2	40.5
Ullage pressure at Engine Start Command (psia)	40.7	38.3	41.9

TABLE 7-2 (SHEET 1 OF 2)
LOX TANK PRESSURIZATION DATA

PARAMETER	S-IVB-205	S-IVB-206	S-IVB-207
Ullage pressure at Engine Start Command (psia)	40.7	38.3	41.9
Minimum ullage pressure during start transient (psia)	35.0	32.9	36.3
Number of secondary flow intervals	8	6	7
LOX tank pressure control (psia)	36.6 to 38.6	36.9 to 38.9	37.43 to 39.45
LOX tank pressurization total flowrate:			
During overcontrol (lbm/sec)	0.34 to 0.40	0.38 to 0.44	0.39 to 0.48
Predicted	0.34 to 0.39	0.34 to 0.40	0.42 to 0.46
During undercontrol (lbm/sec)	0.23 to 0.26	0.27 to 0.31	0.28 to 0.36
Predicted	0.22 to 0.26	0.23 to 0.26	0.29 to 0.33
Helium in cold helium spheres at Engine Start Command (lbm)	338*	251	254
Cold helium sphere pressure at Engine Start Command (psia)	3050	3020	2990

*S-IVB-205 stage utilized eight helium spheres; S-IVB-206 and -207 stages utilized only six.

TABLE 7-2 (SHEET 2 OF 2)
LOX TANK PRESSURIZATION DATA

PARAMETER	S-IVB-205	S-IVB-206	S-IVB-207
Average cold helium sphere temperature at Engine Start Command (deg R)	39.5	40.0	39.7
Helium in cold helium spheres at Engine Cutoff Command (lbm)	194	91	97
Helium consumed during engine firing as calculated from sphere conditions (lbm)	144	160	157
Helium consumption calculated by integration of flowrate (lbm)	136	148	155
Cold helium sphere pressure at Engine Cutoff Command (psia)	1275	700	640
Average cold helium sphere temperature at Engine Cutoff Command (deg R)	48.4	47.3	44.8
Estimated temperature loss in 10 ft of uninsulated line:			
During overcontrol (deg R)	4	14	7
During undercontrol (deg R)	10	38	17
Maximum LOX tank vent inlet temperature* (deg R)	537	530	496

*Redline is 560 deg R.

TABLE 7-3
J-2 HEAT EXCHANGER DATA

PARAMETER	S-IVB-205	S-IVB-206	S-IVB-207
Flowrate through heat exchanger:			
During overcontrol (lbm/sec)	0.22	0.187 to 0.205	0.215
During undercontrol (lbm/sec)	0.075	0.072	0.085
Heat exchanger inlet temperature:			
During overcontrol (deg R)	70	60	60
During undercontrol (deg R)	90	70	73
Heat exchanger outlet temperature*:			
During overcontrol (deg R)	965	974	957
During undercontrol (deg R)	990	1028	1002
Heat exchanger outlet pressure:			
During overcontrol (psia)	335 to 362	358 to 368	335 to 360
During undercontrol (psia)	395 to 410	395 to 420	385 to 407
Heat exchanger outlet temperature at engine cutoff (deg R)	880	930	902
Average LOX vent inlet pressure:			
During overcontrol (psia)	67	68	72
During undercontrol (psia)	46	48	51

*Estimated from measurement C0009 and uninsulated line temperature loss.

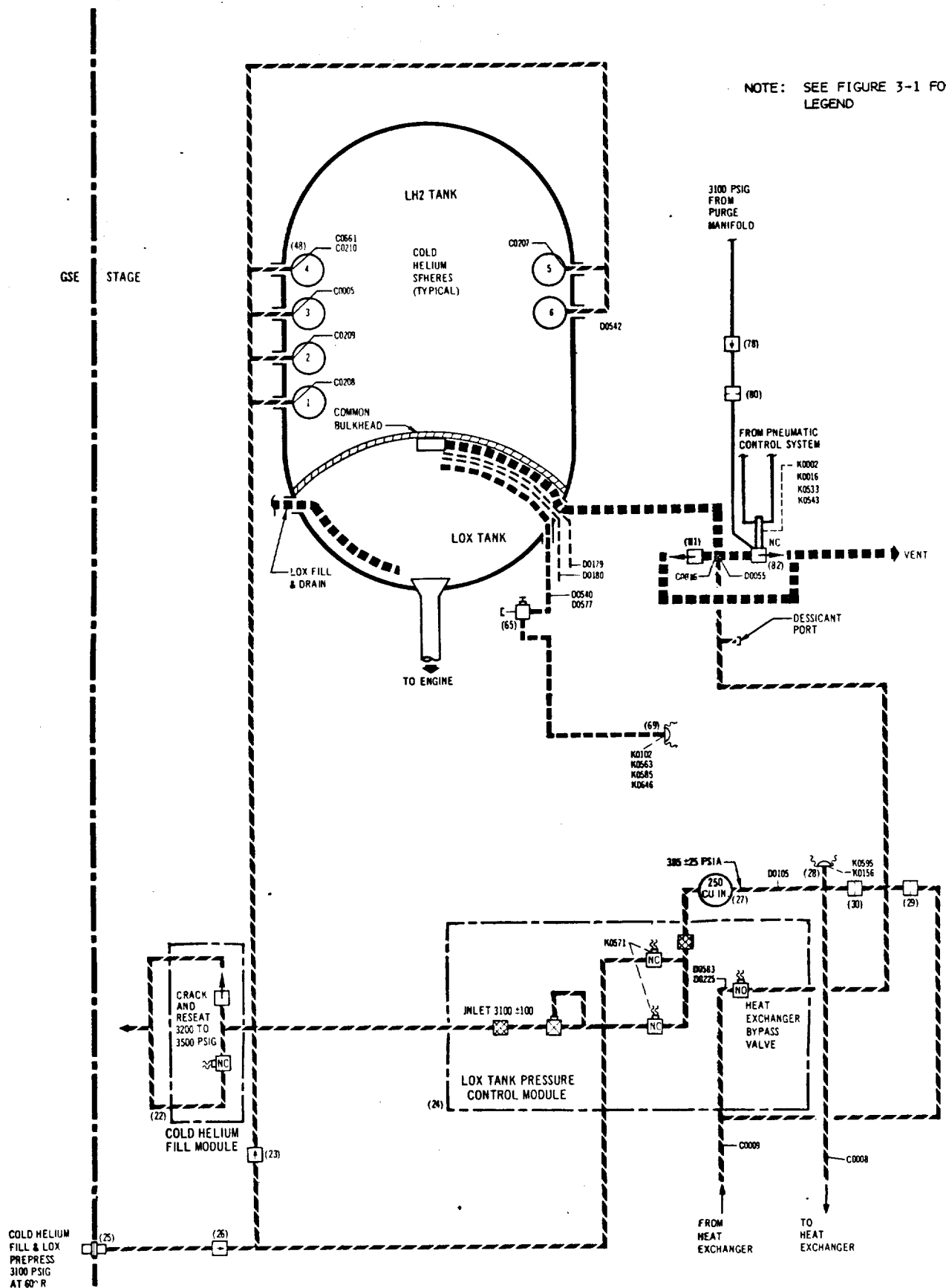


Figure 7-1. LOX Tank Pressurization System

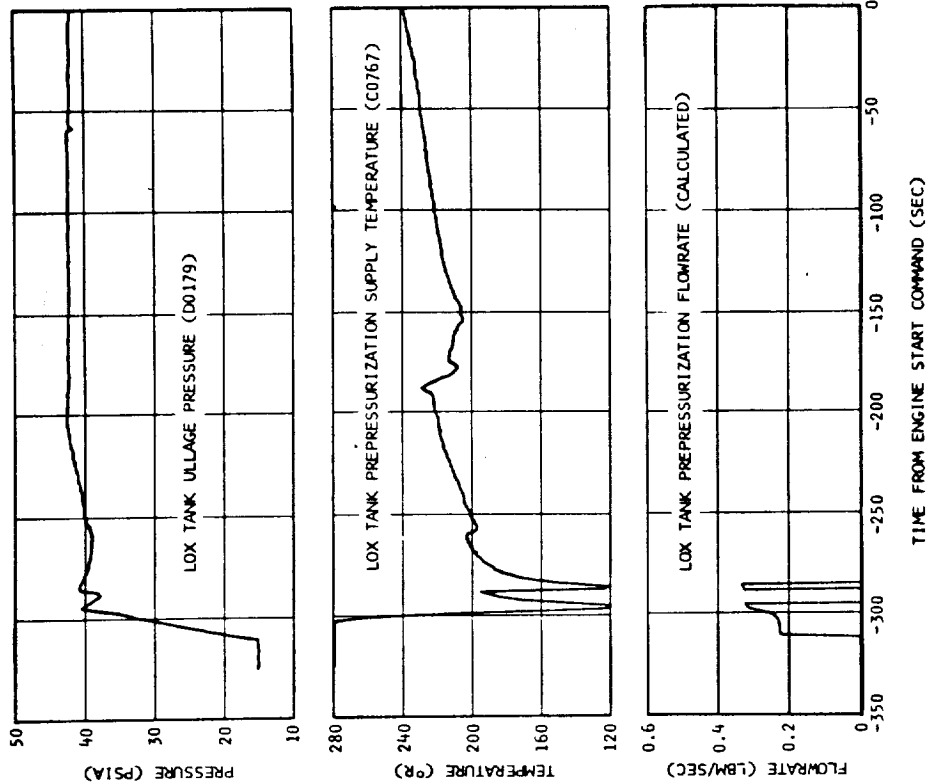
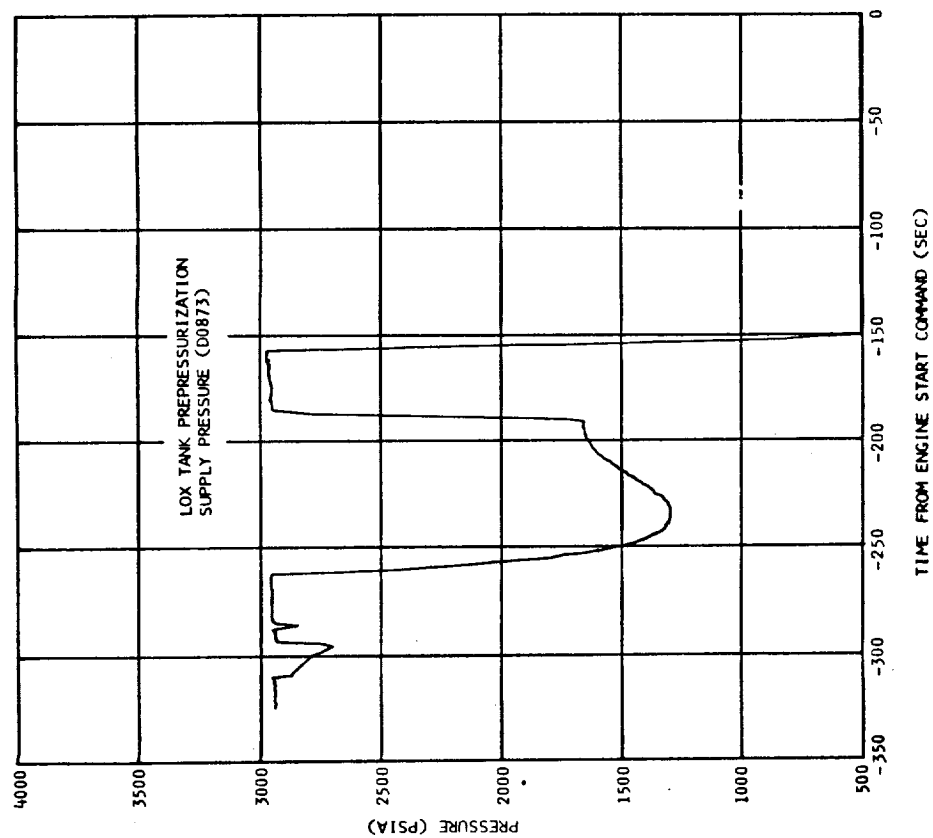


Figure 7-2. LOX Tank Conditions During Prepressurization and Simulated Boost

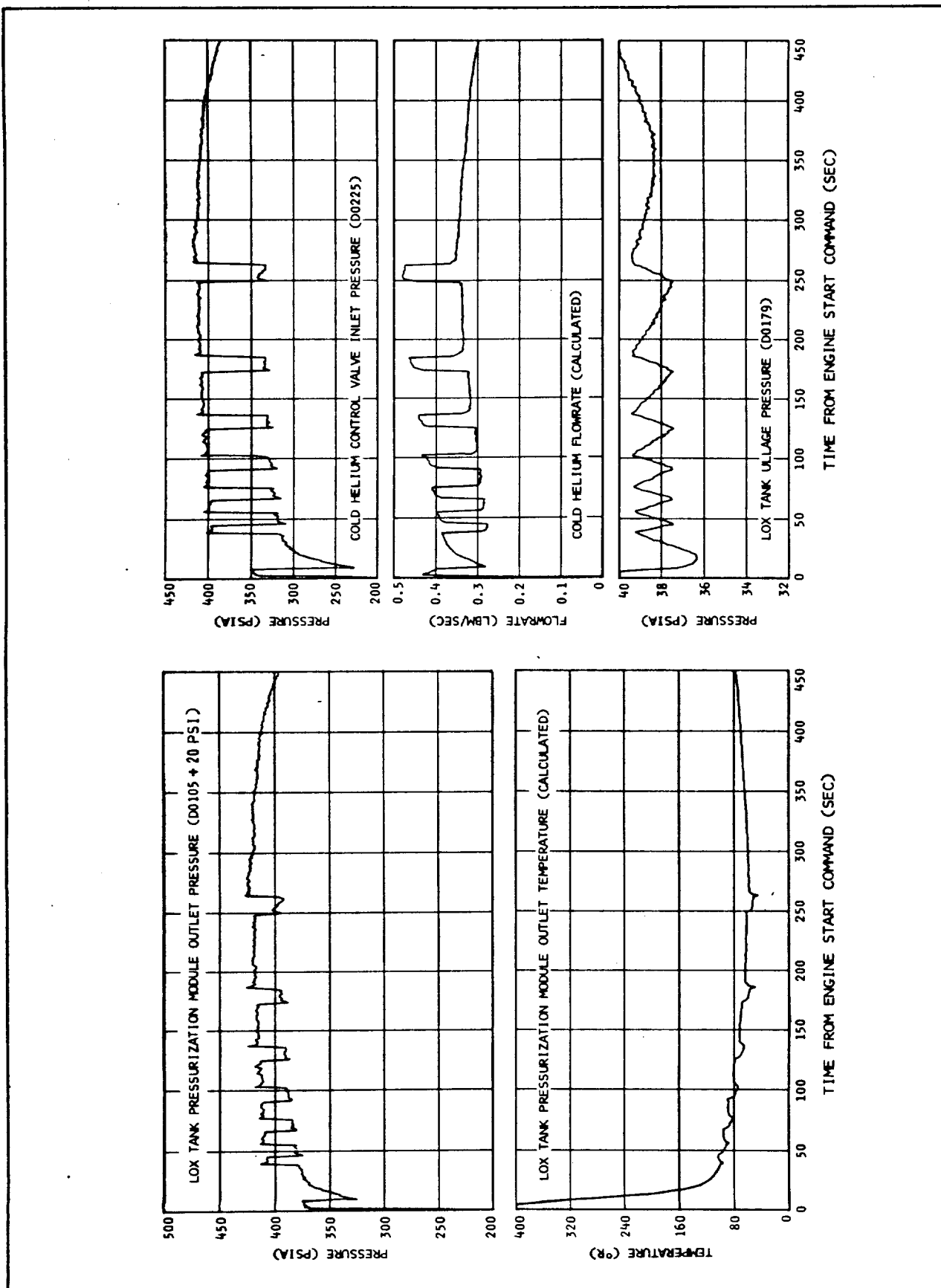


Figure 7-3. LOX Tank Pressurization System Performance

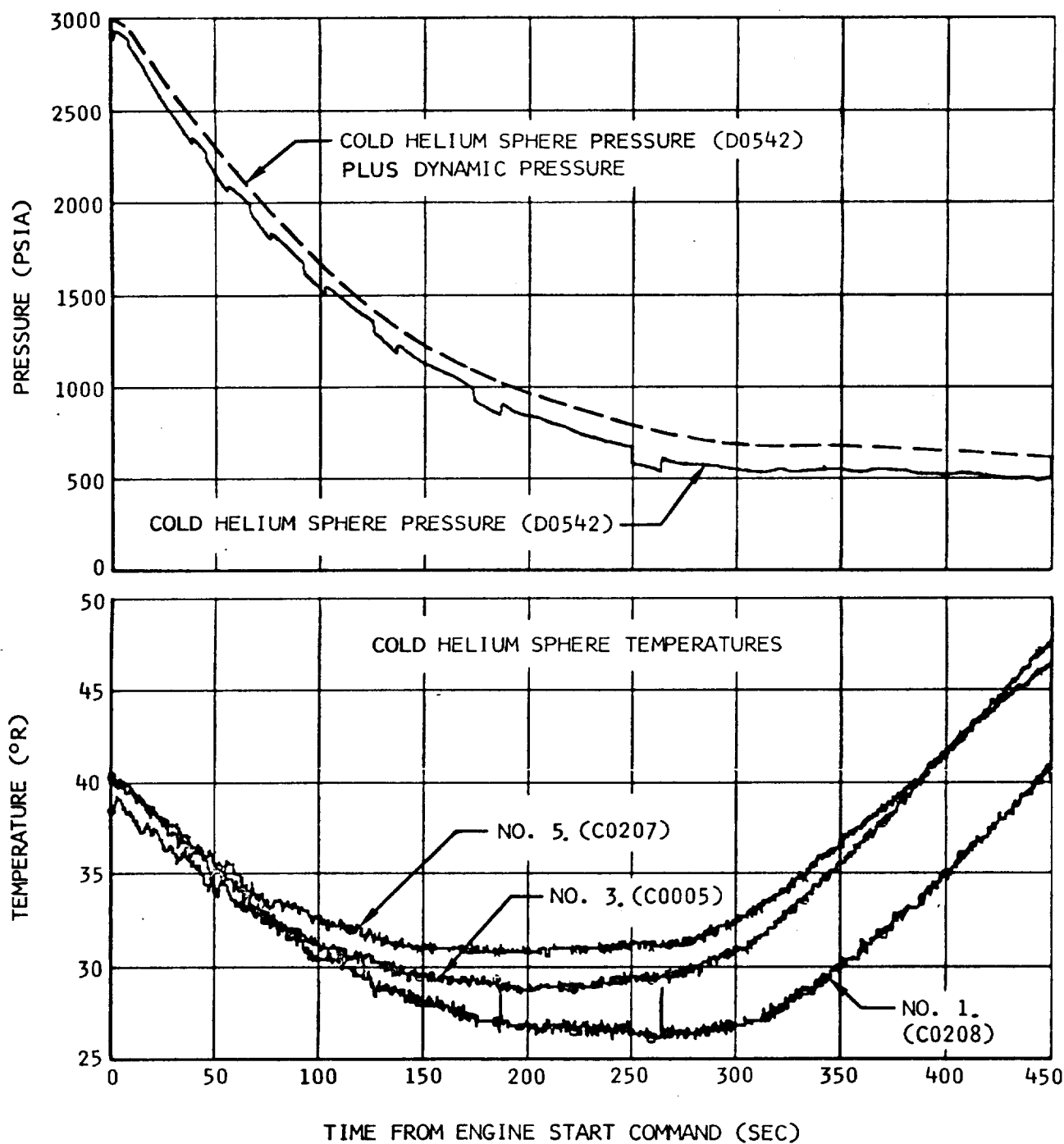


Figure 7-4. Cold Helium Supply

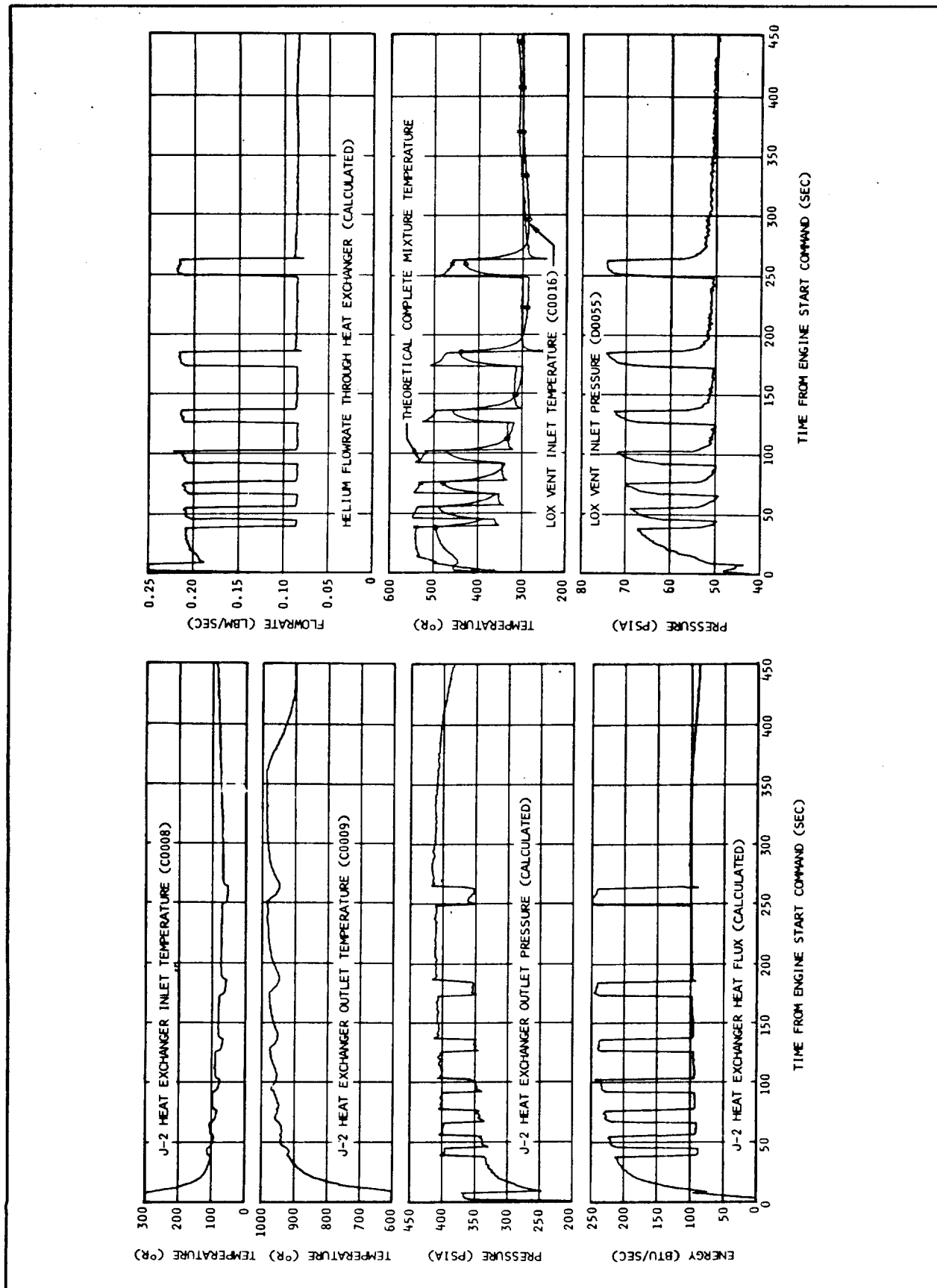


Figure 7-5. J-2 Heat Exchanger Performance

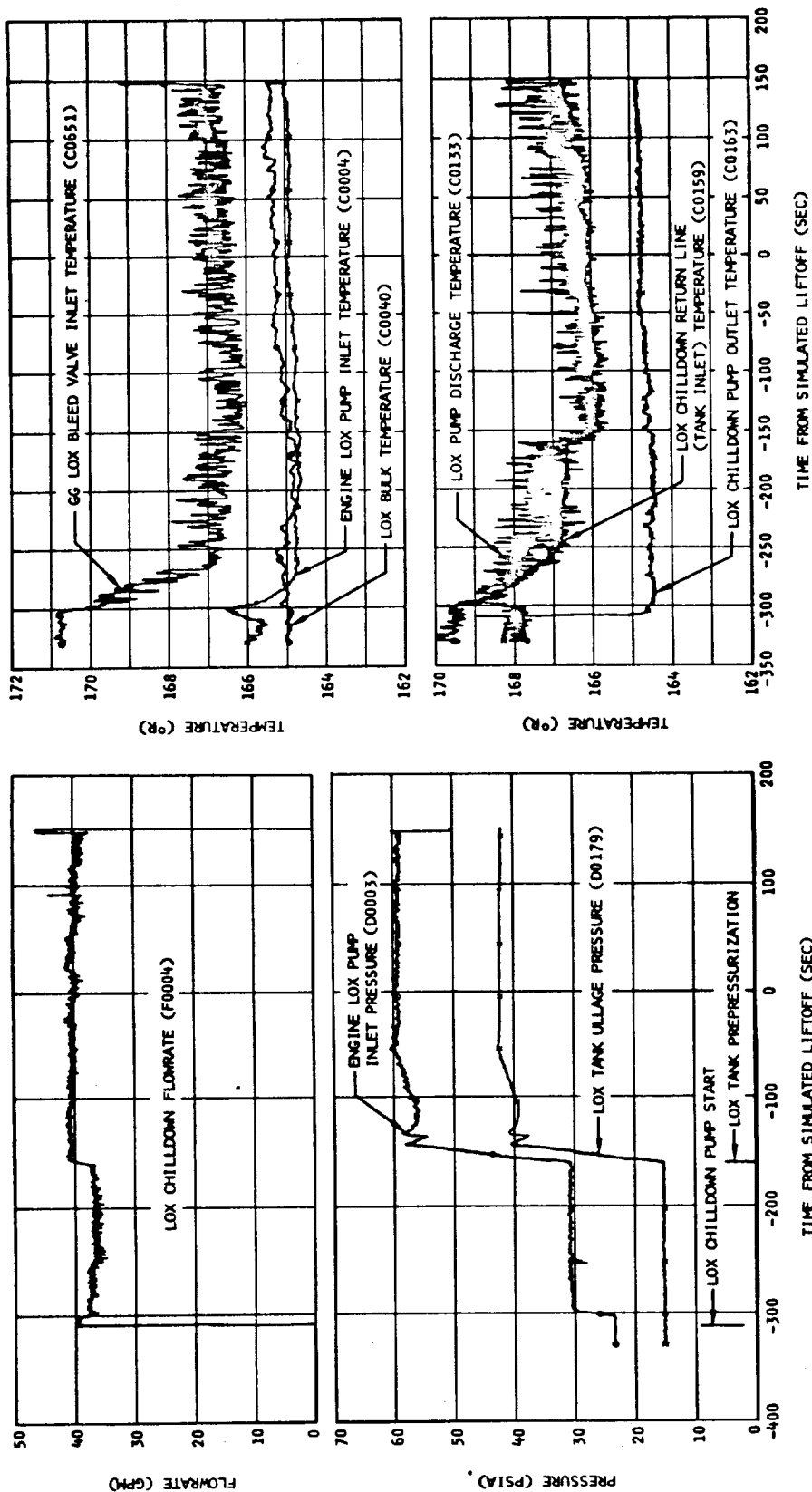


Figure 7-6. LOX Pump Chilldown System Operation

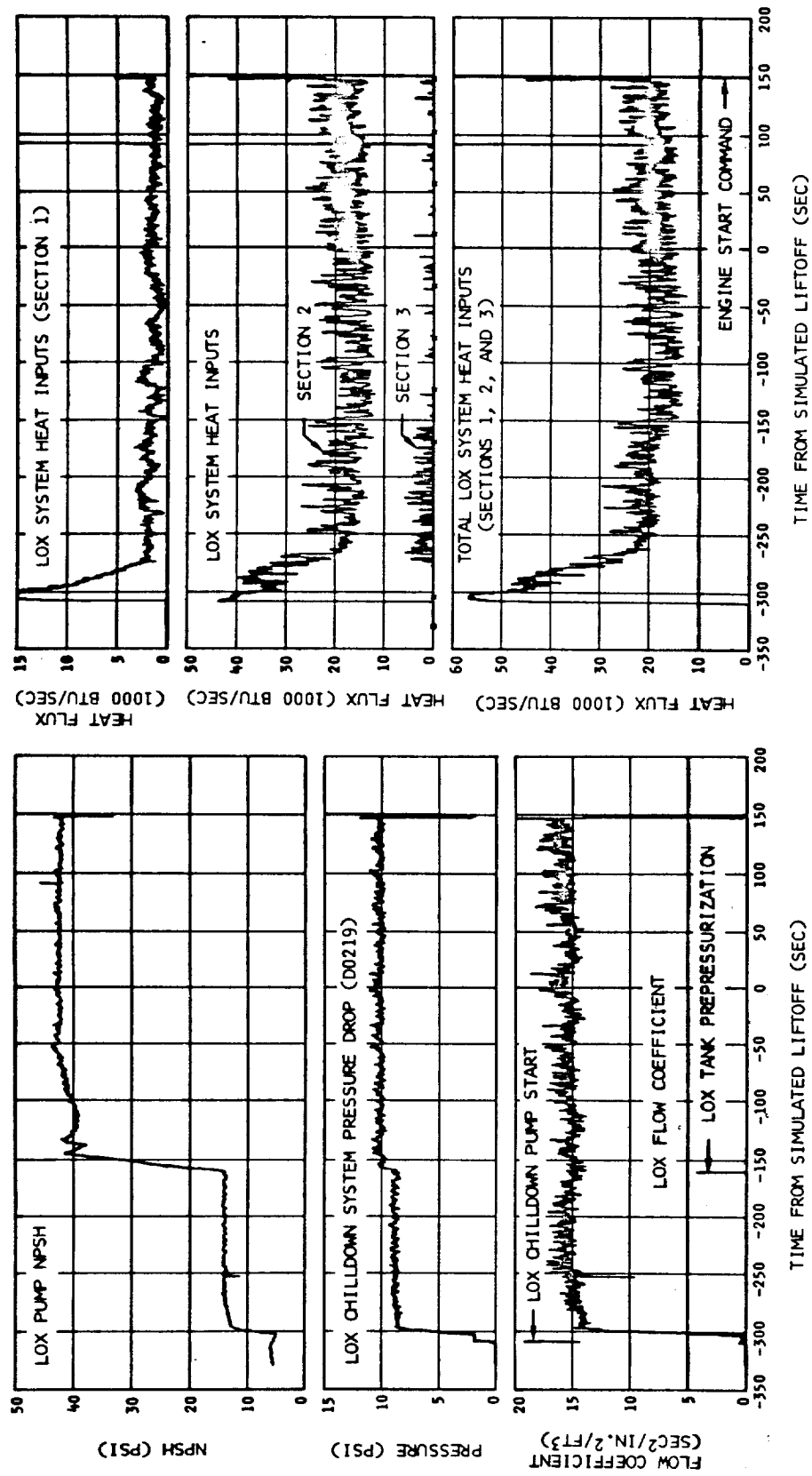


Figure 7-7. LOX Pump Chilldown System Performance

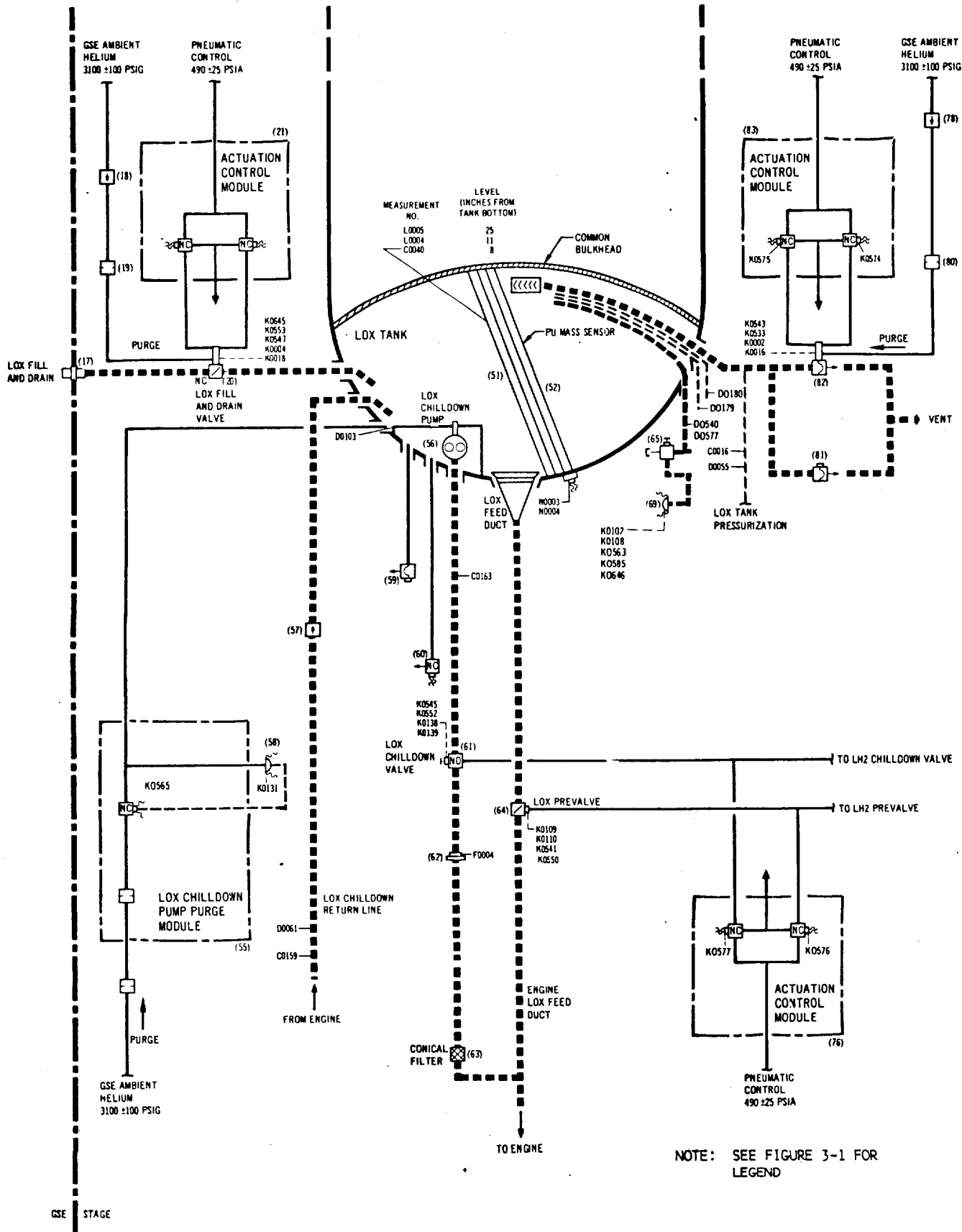


Figure 7-8. LOX Supply System

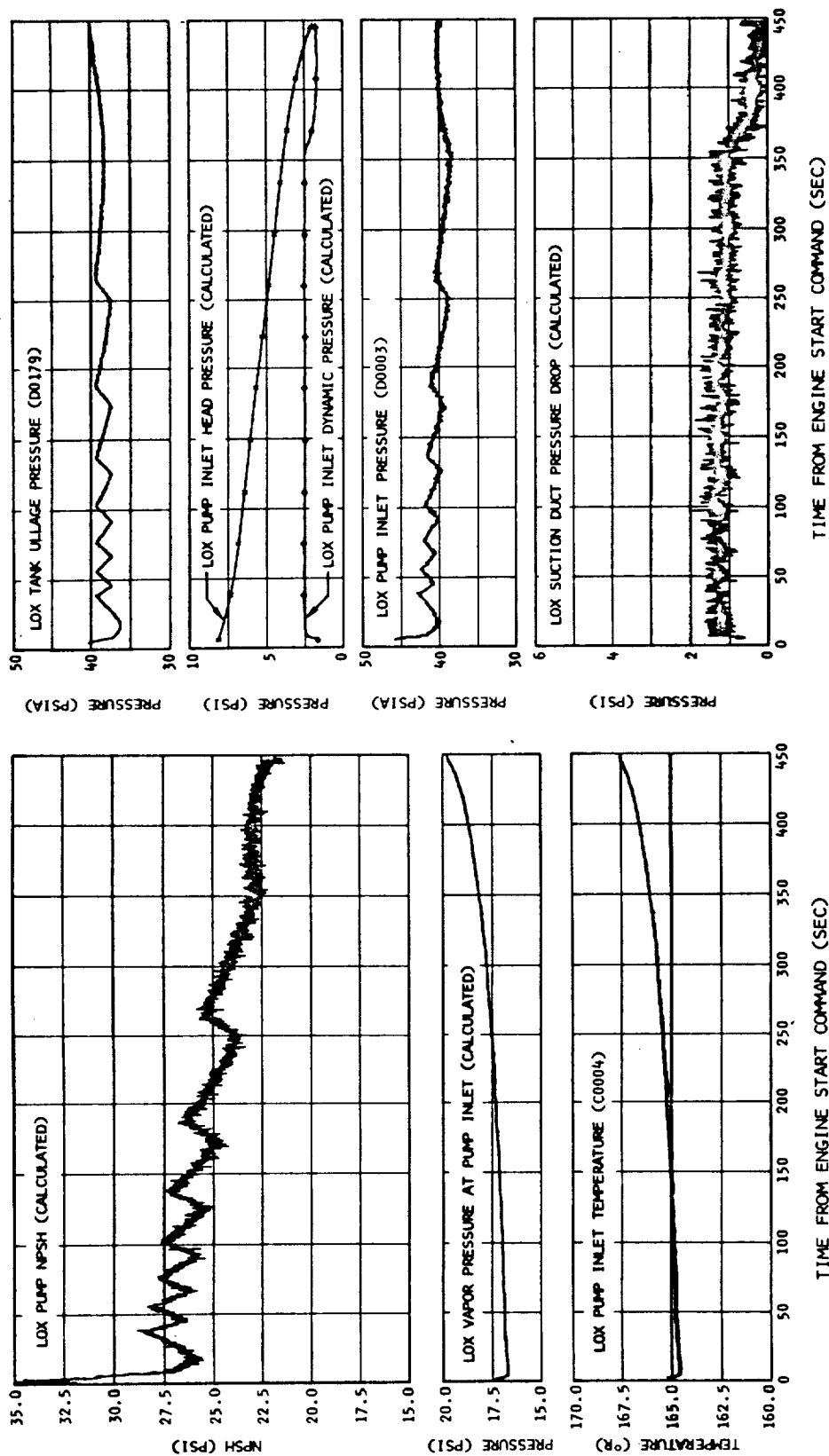


Figure 7-9. LOX Pump Inlet Conditions

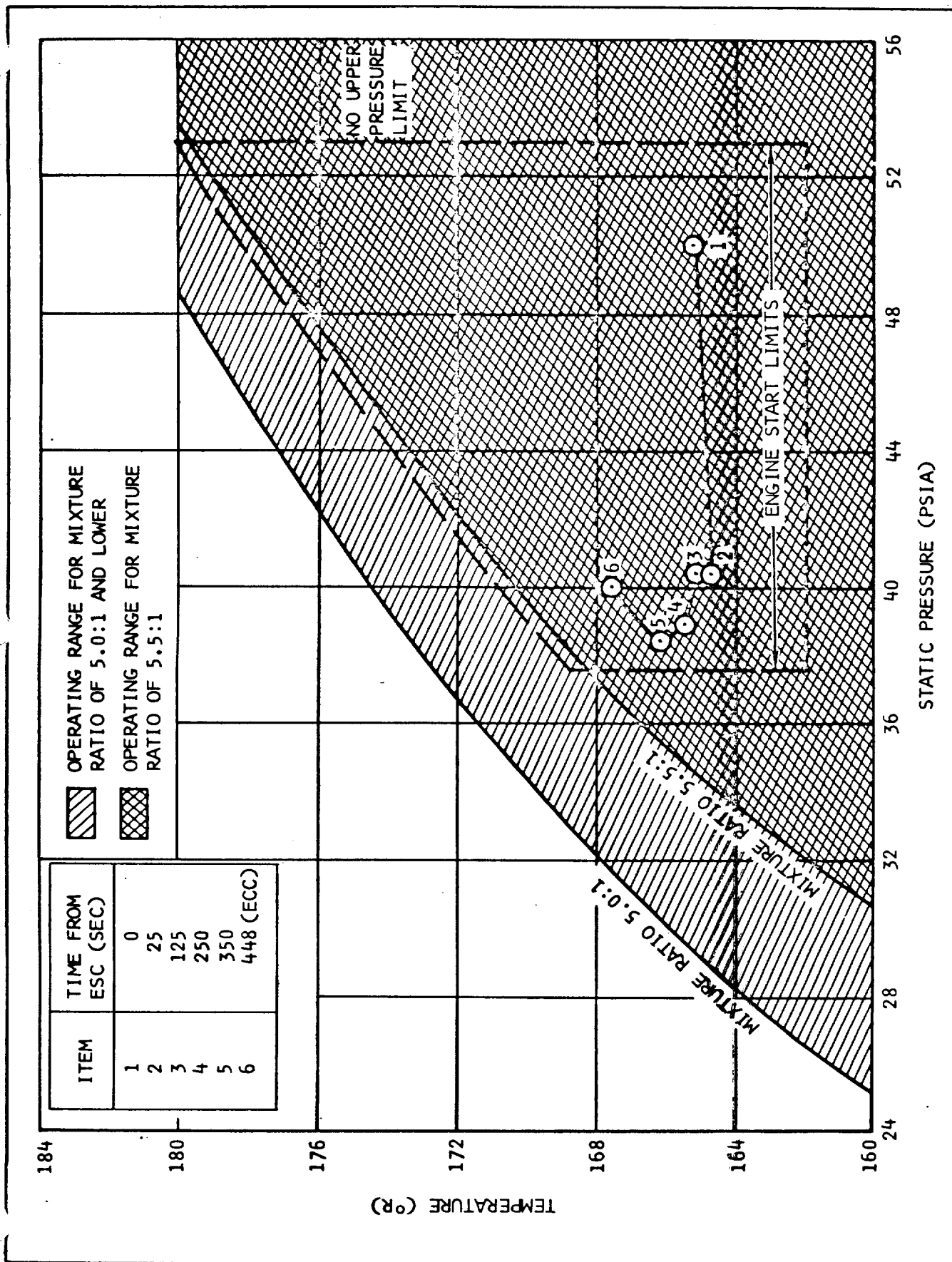


Figure 7-10. LOX Pump Inlet Conditions During Firing

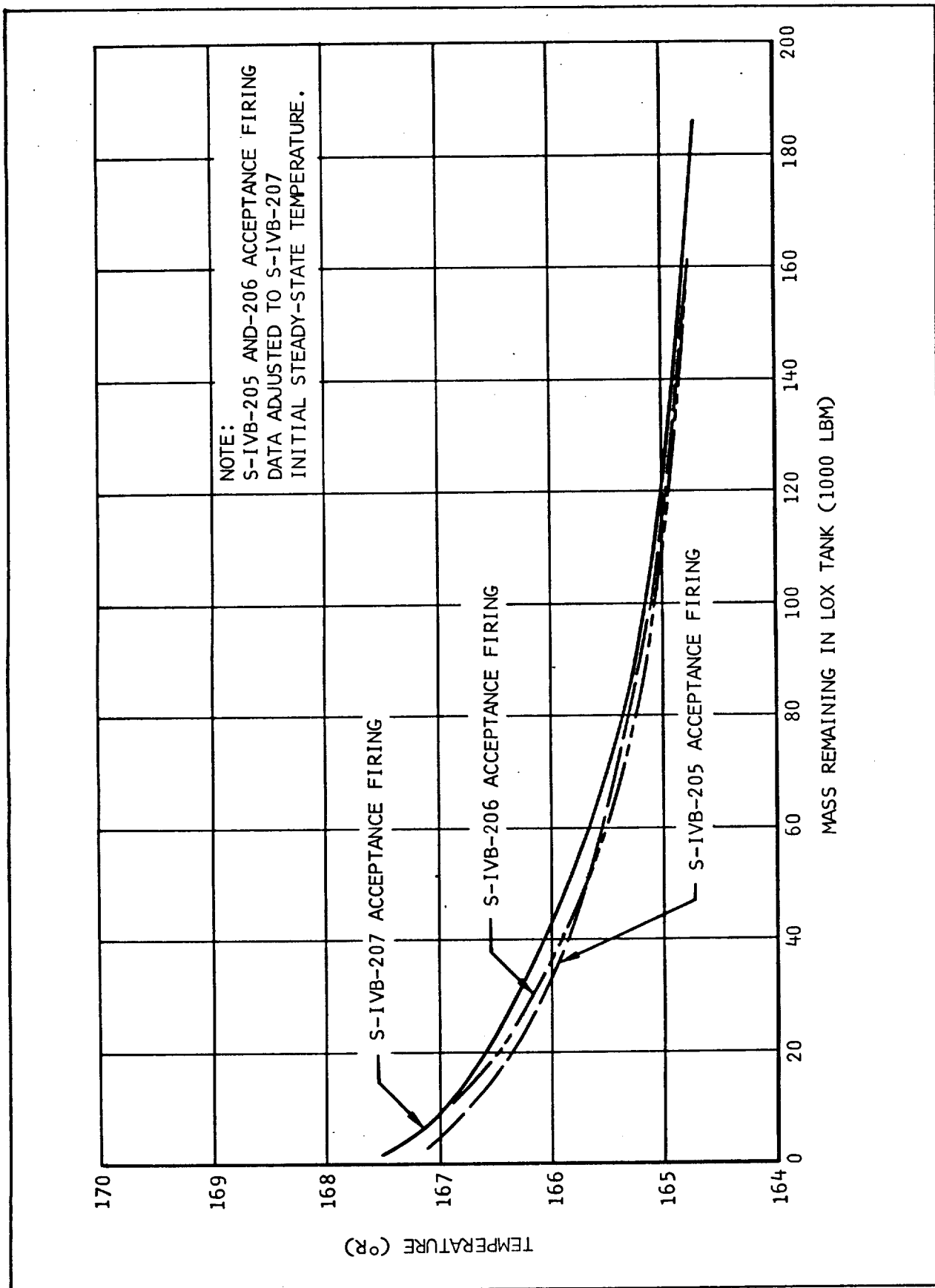


Figure 7-11. Effect of LOX Mass Level on LOX Pump Inlet Temperature

SECTION 8

FUEL SYSTEM

8. FUEL SYSTEM

The fuel system performed as designed and supplied LH2 to the engine within the limits defined in the engine specification.

8.1 Pressurization Control

The LH2 tank pressurization system (figure 8-1) performed adequately and satisfactorily controlled LH2 tank ullage pressure throughout the acceptance firing.

8.1.1 Prepressurization

LH2 tank helium prepressurization from GSE console B was nominal. Data are presented in figure 8-2 and compared with S-IVB-206 data in table 8-1. After prepressurization was terminated and until Engine Start Command, the ullage pressure increase (figure 8-2) was a result of the ullage temperature increasing because of ambient heat input.

8.1.2 Pressurization

During engine operation LH2 tank pressurization was satisfactorily accomplished by the GH2 engine tapoff system (figure 8-1). The data are presented in table 8-2 and figure 8-3 and show that all measured parameters were within the normal dispersion range observed in previous acceptance firings. The low calculated values of propellant boiloff and pressurant collapse factor attest to the effectiveness of the nylon bag pressurant inlet diffuser.

The LH2 tank relief valve cracked open at ESC +408 sec, during step pressurization, and continued relieving until Engine Cutoff Command. This was a result of step pressurization which occurred near the end of an overpressurization cycle with the high ullage pressure at that time being reflected throughout step pressurization.

8.2 LH2 Pump Chillover

The LH2 pump chillover system performance was marginal, with pump inlet conditions at engine start of 38.2 psia and 41.6 deg R producing an NPSH of 6.8 psi. The decline in performance from that of previous

stages was a direct result of an unusually high level of heat flux into the chilldown system; however, at this time, this cannot be attributed to any specific source, and there were no contributing hardware malfunctions. The low level of NPSH at Engine Start Command did not result in unfavorable conditions during the engine start transient. System data and performance calculations are presented in figures 8-4 and 8-5 and compared with previous acceptance firing data in table 8-3.

Prior to the initiation of recirculation chilldown, the system was filled with liquid at saturated conditions and the hardware had been exposed to the LH2 for several hours. In spite of this, the chilldown pump outlet temperature showed superheated gas, indicating an unusually high heat input rate in the area of the chilldown pump and shutoff valve. At the initiation of recirculation, this temperature quickly became saturated and then subcooled, although heat input was sufficient to prevent subcooling at the engine pump inlet and the remainder of the system during the period prior to tank ullage pressurization. After the LH2 tank was pressurized, subcooled conditions were obtained at the J-2 engine but the chilldown system return line exit remained at saturation temperature. An unusual phenomenon occurred both before and after prepressurization. The chilldown pump outlet temperature indicated subcooled levels while, during prepressurization, it responded to what appeared to be the change in saturation temperature. This would seem to indicate a change in heat input in this area (chilldown pump and shutoff valve) during prepressurization.

The flowmeter and chilldown pump differential pressure verify the conditions observed, with the high flow and low pressure followed by a period of low flowrate and high pressure, both at chilldown pump initiation and prepressurization, indicating a partial gas collapse followed by the high flow impedance offered by the gas remaining in the system. In addition, the steady-state flowrate prior to prepressurization is slightly lower than normal (85 gpm vs 100 gpm) and the pressure is higher (10 psid vs 9 psid), both of which conditions indicate excessive vaporization in the system.

Before any calculations were made, the various data were observed during a quiescent period prior to initiation of recirculation, with the result that three measurements (C0161, C0650, and D0218) were biased to make them consistent with the remainder of the data.

The flow coefficient, which is a measure of the chilldown system flow resistance, was higher than in previous acceptance firings; however, this result must be qualified because an unknown amount of vaporization occurred in the system return line during pressurized chilldown. The flow coefficient is calculated from data obtained during this period because normally vapor is not present and this allows the use of liquid density in the equation from which the flow coefficient is calculated. In this instance the use of liquid density instead of the correct two-phase density (which is unknown but definitely lower) results in a calculated flow coefficient that is too high. As the average of the flow coefficient values obtained during pressurized chilldown is used to estimate fluid quality during unpressurized chilldown, the error also affects the latter value. The estimate of fluid quality and thus also the calculated heat input causing this amount of vaporization will be lower than actually occurred.

The heat inputs to the chilldown system itemized in table 8-3 contain several apparent inconsistencies, particularly in the light of the preceeding paragraphs, which may be rationalized with the following information. Due to instrumentation limitations, it is not possible to calculate the heat input resulting in LH2 vaporization in section 1 during unpressurized operation. The 24,000 Btu/hr during this period then is representative only of the sensible heat. The heat input going into LH2 vaporization calculated from the fluid quality estimate was arbitrarily assigned to sections 2 and 3. The heat input value for the combination of these two sections may thus be high (if it offsets the error in fluid quality) as some vaporization actually occurred in section 1, but the total heat input (into all sections) is definitely lower than actually resulted because of the error in fluid quality. The unusually high level of heat input to sections 2 and 3 (38,000 Btu/hr) can also be partially attributed to the film of condensed nitrogen which was noted on the system return line.

Due to the limitations of the method used, the heat input going into LH2 vaporization in section 3 during pressurized chilldown cannot be calculated. The values presented for section 3 and total are then low by the amount of the heat input going into LH2 vaporization. If the assumption is made that the heat input to sections 2 and 3, calculated during unpressurized chilldown, is approximately correct for pressurized chilldown as well, the apparent total heat input to the system is 87,000 Btu/hr. The only previous stage with a comparably high level was S-IVB-204 with 79,000 Btu/hr. On that stage the helium purge around the recirculation line was insufficient (14 scfm vs normally used 65 scfm).

The NPSH required prior to engine start to guarantee a liquid head to the pump during the start transient was 6.3 psi. Within the limitations of data accuracy, it would appear that the calculated value of 6.8 fulfilled this requirement; however, a primary factor in calculating NPSH is the LH2 pump inlet temperature (C0003), and throughout pressurized chilldown this measurement was noisy and its absolute value cannot be determined.

As indicated in the previous paragraphs, the difficulty in the chilldown system appears to have been an excessive heat input in section 1 of the system. Comparison of temperature levels with previous acceptance firings show that the temperature differential, under subcooled conditions, from the chilldown pump outlet to the engine pump inlet was normal (0.8 deg R vs an average 1.0 deg R at Engine Start Command). This, together with the superheated conditions at the chilldown pump outlet prior to recirculation, tends to show that the abnormal heat input is in the vicinity of the chilldown pump and shutoff valve. Calculations indicate that 37,500 of the 49,000 Btu/hr observed in section 1 occurred in this area. Various possible sources of this heat were considered and are discussed in the following paragraphs.

- a. An inactive or insufficient helium purge of the chilldown valve fairing allowing GN2 to migrate into the fairing and condense on the hardware, providing a much greater heat source than the normal helium environment. This purge line was checked after the firing and found to be correctly installed and to have the proper flow of 65 scfm. No measurement of the pressure across the fairing was made during the firing.
- b. The foam insulation around the chilldown pump and valve, being missing or poorly installed, allowing ambient heat to more freely penetrate the system. Although the insulation was removed after the firing and could not be inspected, it was verbally verified that the insulation was installed and that the quality of the installation was equivalent to previous stages.
- c. A helium leak in the shutoff valve actuator injecting ambient (530 deg R) helium directly into the LH2. The valve was leak checked and found to be leak tight.
- d. An electrical condition in the chilldown pump motor causing unusually high heating. Although specific data are not available, stage electrical system data show no unusual current loads.

However the following should be noted:

- a. High recirculation pump outlet temperature prior to recirculation start indicated an external heat source.
- b. Heat transfer from external source cannot be from the helium purge because of the magnitude; therefore it is more likely that condensation of GN2 occurred. Air condensation was also possible but doubtful as air is usually moist and would form an ice insulation which reduces heat input.

8.3 Engine LH2 Supply

The engine LH2 supply system (figure 8-6) provided LH2 to the engine within specifications throughout the firing. The minimum available NPSH during firing was 9.5 psi, which was above the allowable minimum of 5.8 psi at high EMR and 5.57 psi after EMR cutback. The LH2 pump inlet static pressure was 38.2 psia at engine start. It then followed the ullage pressure, reaching a minimum of 27 psia at ESC +150 sec. After step pressurization, the pressure increased and was 37.5 psia at engine cutoff. After the start transient, the LH2 temperature at the pump inlet was 37.4 deg R and increased with bulk heating to a maximum of 39 deg R shortly before engine cutoff (figure 8-7).

The available NPSH at the LH2 pump inlet at engine start was approximately 6.8 psi. It increased to a maximum of 19.6 psi shortly after engine start as the warmer LH2 in the suction duct was replaced by the colder LH2 from the tank, resulting in a lower saturation pressure at the pump inlet. The NPSH then followed the ullage pressure, decreasing to a minimum of 9.5 psi at ESC +270 sec, which was above the 5.8 psi required at that time. It increased after the initiation of step pressurization at ESC +300 sec and continued to increase until ESC +408 sec, when the LH2 tank started relieving. From this time on the NPSH started to decrease slightly, reaching 16 psi at engine cutoff.

The LH2 pump inlet pressure and temperature were plotted in the engine operating region (figure 8-8) and showed that the LH2 pump inlet condition was met satisfactorily throughout the firing. Figure 8-9 is a plot of the pump inlet temperature versus the mass remaining in the LH2 tank during burn and includes previous acceptance firing data for comparison. The S-IVB-207 data agreed closely with the S-IVB-205 and -206 data.

TABLE 8-1
LH2 TANK PREPRESSURIZATION DATA

PARAMETER	S-IVB-206	S-IVB-207
Prepressurization initiation (sec from T_0)	-110.1	-110.7
Prepressurization termination (sec from T_0)	-41.6	-39.1
Prepressurization duration (sec)	68.5	71.6
Helium mass used during prepressurization (lbm)	36.4	38.72
Time of tank relief (sec from T_0)	Not Applicable	
Ullage pressure at prepressurization termination (psia)	33.6	34.1
Ullage pressure at simulated liftoff (psia)	35.0	34.7
Ullage pressure at Engine Start Command (psia)	37.6	37.4
Ullage pressure at relief valve open (psia)	Not Applicable	
Ullage pressure rise rate after prepressurization (psi/min)	1.22	1.04

TABLE 8-2
LH2 TANK PRESSURIZATION DATA

PARAMETER	S-IVB-206	S-IVB-207
Number of control cycles	2	2
Control pressure switch range (psia)	26.8-29.1	27.1-29.3
Ullage pressure at Engine Start Command (psia)	37.6	37.4
Ullage pressure at step pressurization (psia)	29.1	28.5
Ullage pressure at Engine Cutoff Command (psia)	38.6	38.9
Time of step pressurization (sec from ESC)	301.1	301.3
GH2 pressurant flowrate -		
Undercontrol (lbm/sec)	0.35	0.36
Overcontrol (lbm/sec)	0.63	0.65
Step before cutback (lbm/sec)	1.12	1.10
Step after cutback (lbm/sec)	1.04	0.99
Total GH2 pressurant mass (lbm)	281.6	281.2
Time of relief valve opening (sec from ESC)	407	408
Pressure at relief valve operation (psia)	38.4	38.35
LH2 boiloff during engine operation (lbm)	0	0

TABLE 8-3
FUEL SYSTEM PERFORMANCE DATA

PARAMETER	S-IVB-205	S-IVB-206	S-IVB-207
Maximum NPSH (psi)	23.8	25.5	15.9
NPSH at ESC (psi)	16.5	18.0	6.8
Average flow coefficient ($\text{sec}^2/\text{in.}^2\text{-ft}^3$)	15.2	18.2	18.95
LH2 quality-sections 2 & 3 unpressurized			
Maximum (lbm gas/lbm mixture)	0.043	0.033	0.377
At prepres (lbm gas/lbm mixture)	0.036	0.025	0.067
LH2 pump inlet at Engine Start Command			
Static pressure (psia)	39.5	38.5	38.2
Temperature (deg R)	39.1	38.6	41.6
Chiltdown system heat absorption rate* (Btu/hr)			
Unpressurized			
Section 1	25,000	21,000	24,000+
Sections 2 and 3	25,000	18,000	38,000
Total	50,000	39,000	62,000+
Pressurized			
Section 1	21,000	17,500	49,000
Section 2	13,000	22,000	10,000
Section 3	32,000	21,500	13,500+
Total	66,000	61,000	72,500+
Events (sec from T_0)			
Chiltdown start	-307.5	-305.1	-505.6
Prevalve closed		-301.8	-301.9
Prepressurization	-152	-110.1	-110.7
Prevalve (start) open	147.5	147.22	147.86
Chiltdown pump off	150.7	150.2	150.26
Chiltdown shutoff valve closed	150.89	150.34	150.44
Engine Start Command	151.34	150.16	150.86

* Section 1 is tank to pump inlet, section 2 is pump inlet to bleed valve; section 3 is bleed valve to tank.

† These values represent only the sensible heat observed in sections 1, and 3. Due to instrumentation limitations, the heat input going into LH2 vaporization cannot be calculated in sections 1, and 3.

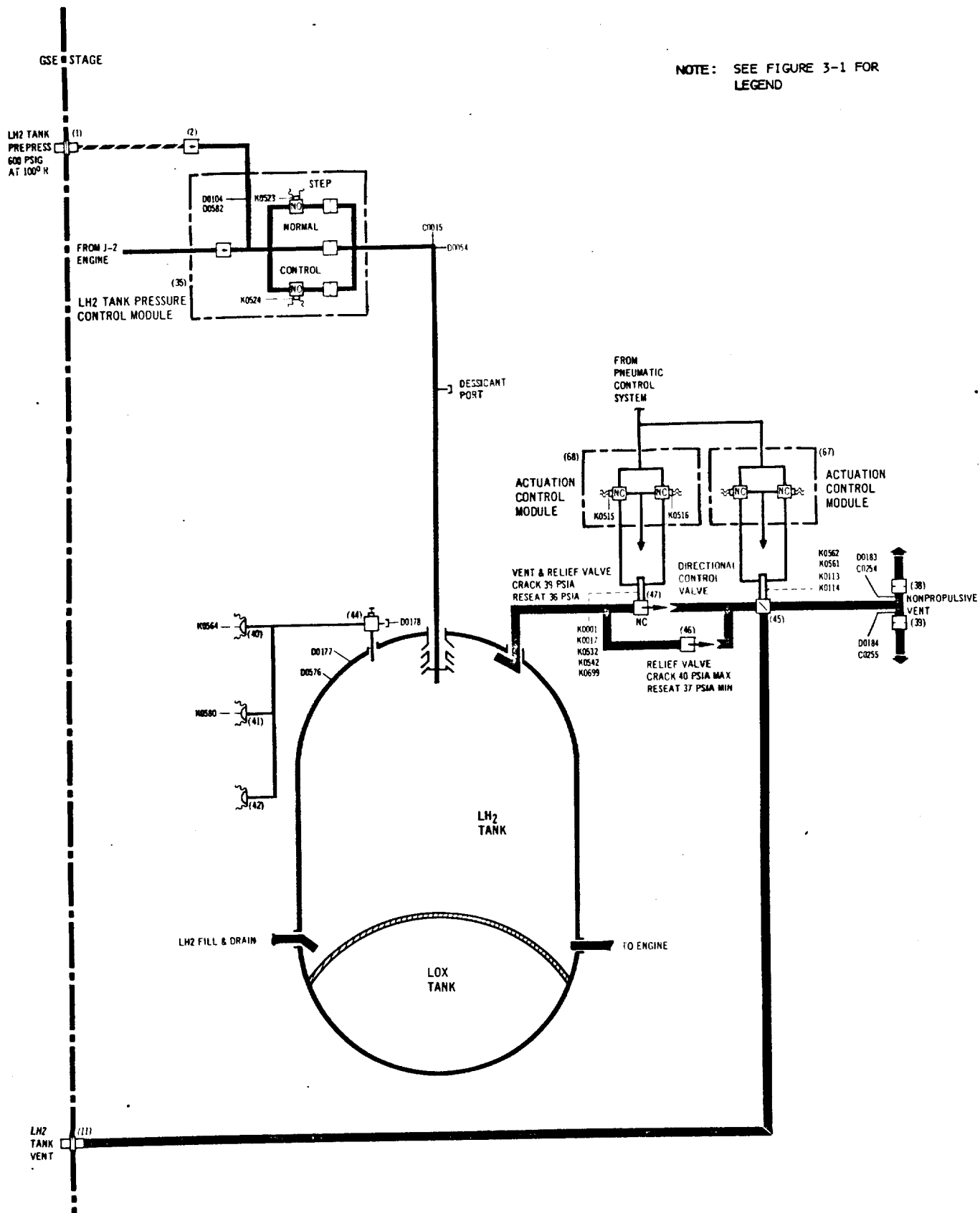


Figure 8-1. LH2 Tank Pressurization System

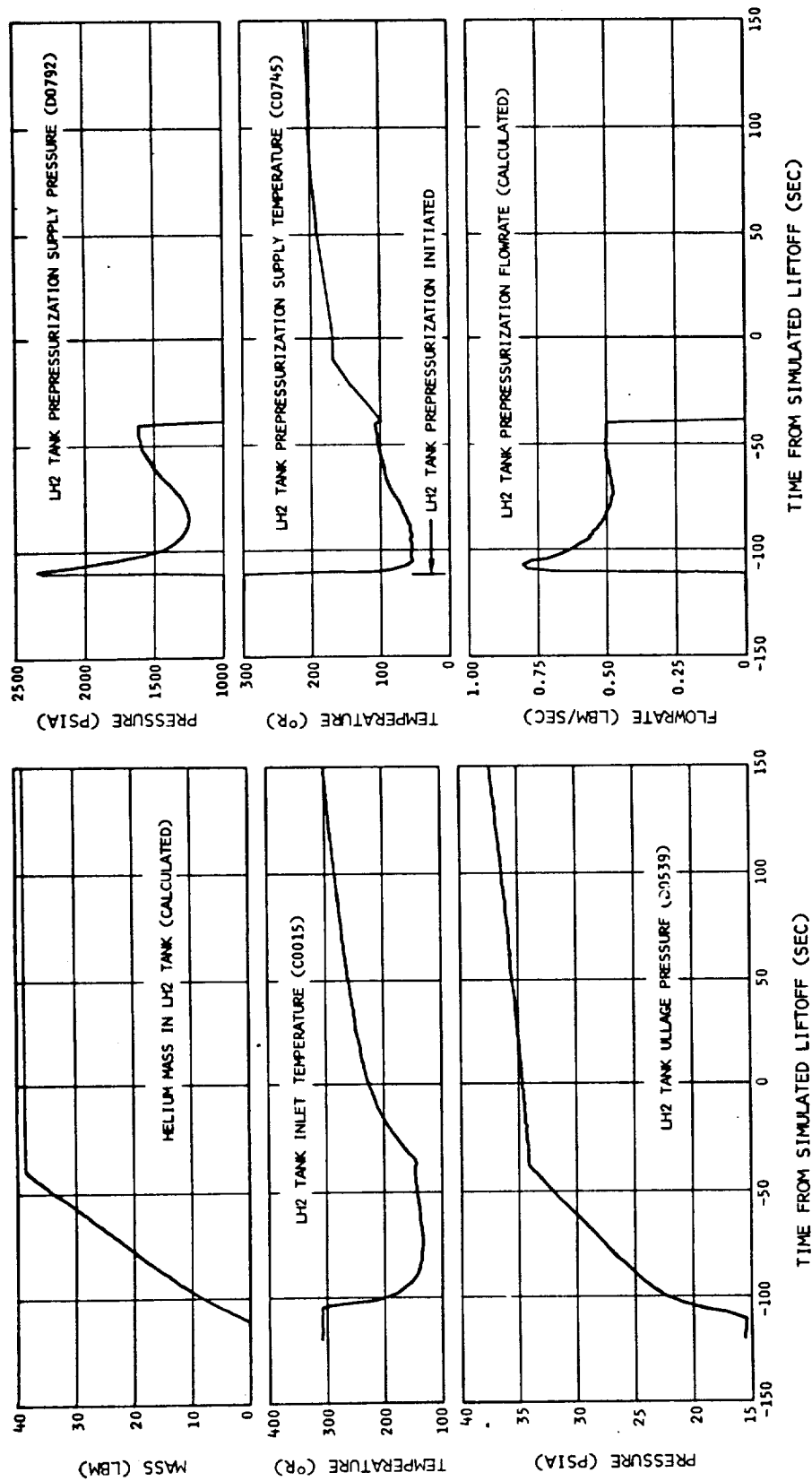


Figure 8-2. LH2 Tank Prepressurization System Performance

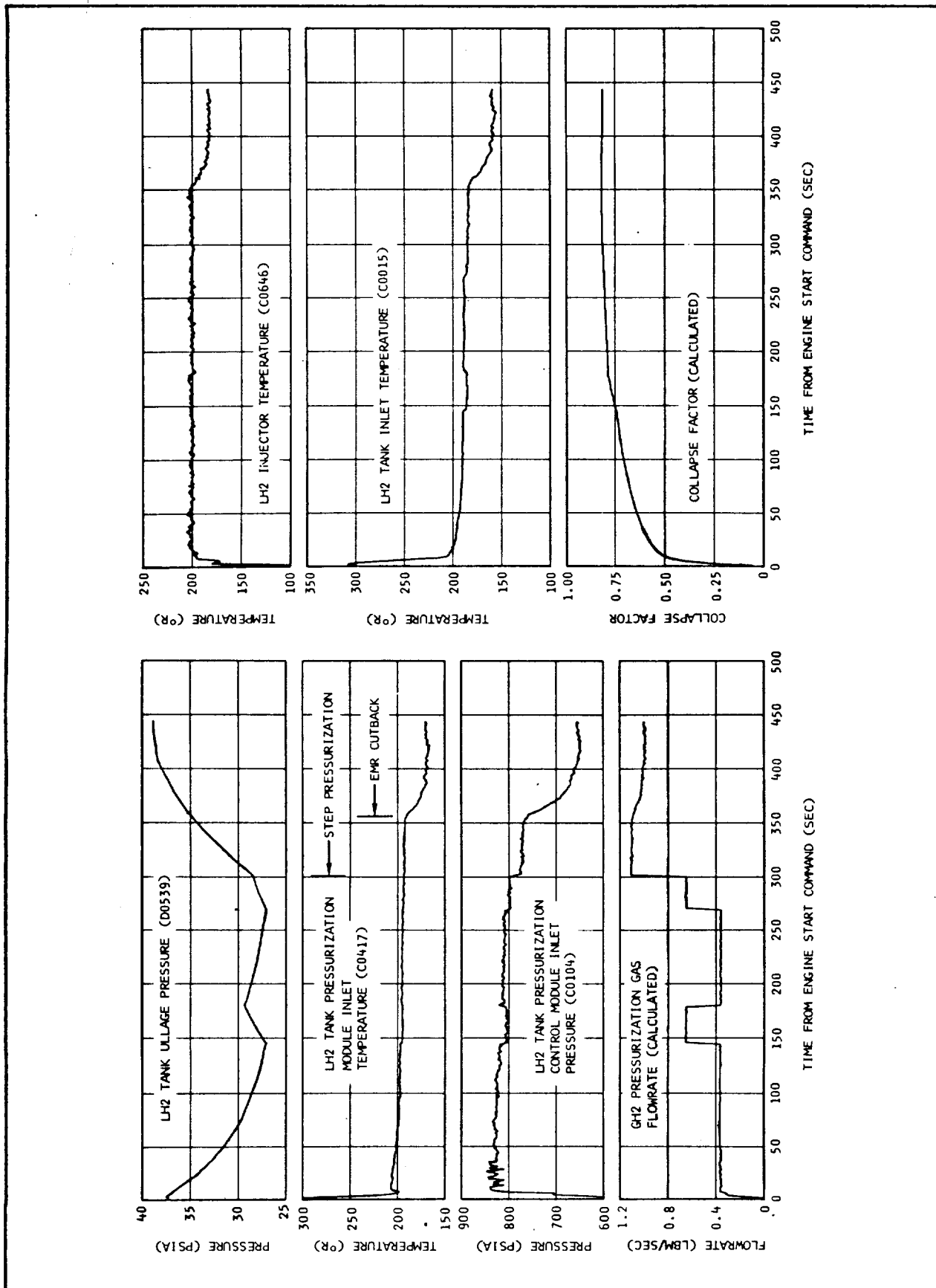


Figure 8-3. LH2 Tank Pressurization System Performance

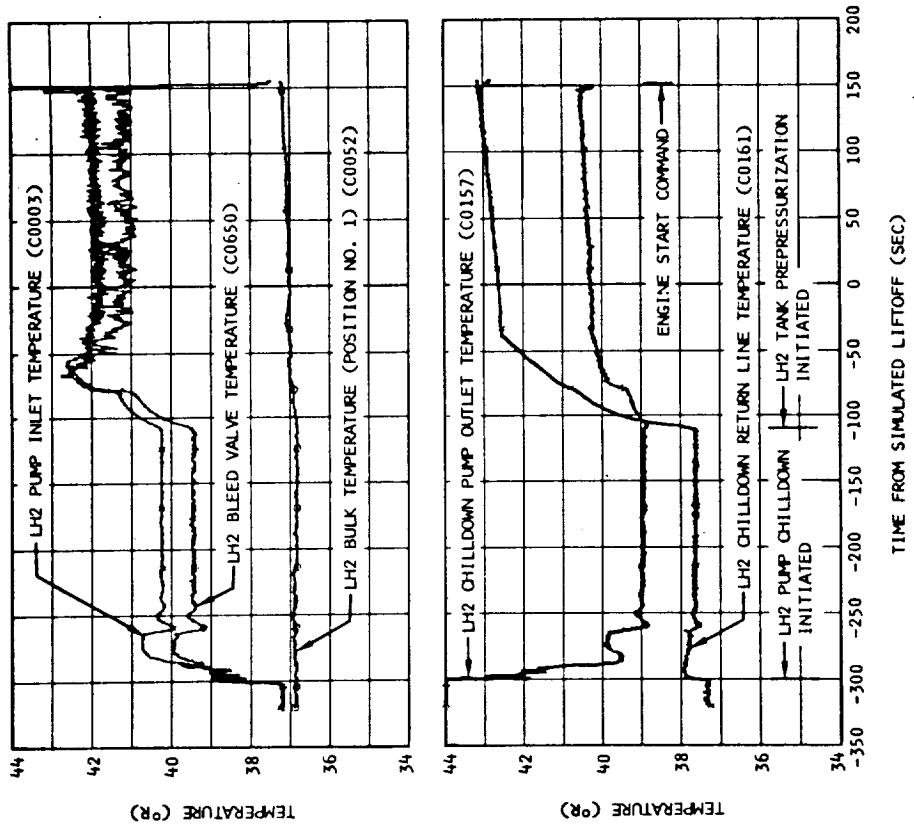
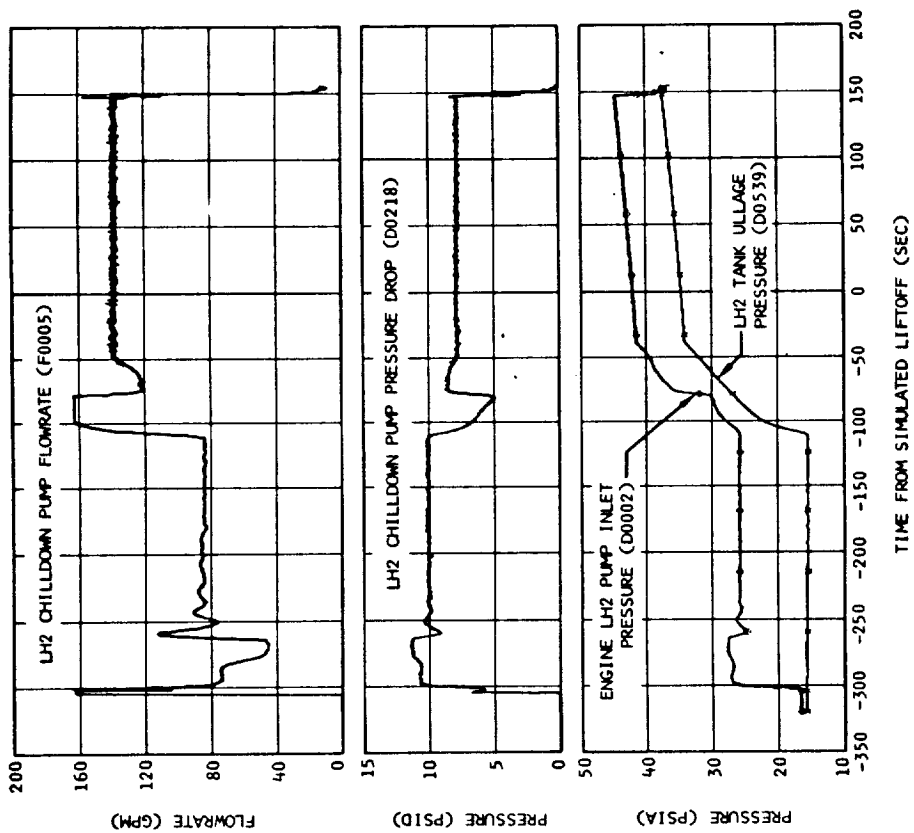


Figure 8-4. LH2 Pump Chilldown

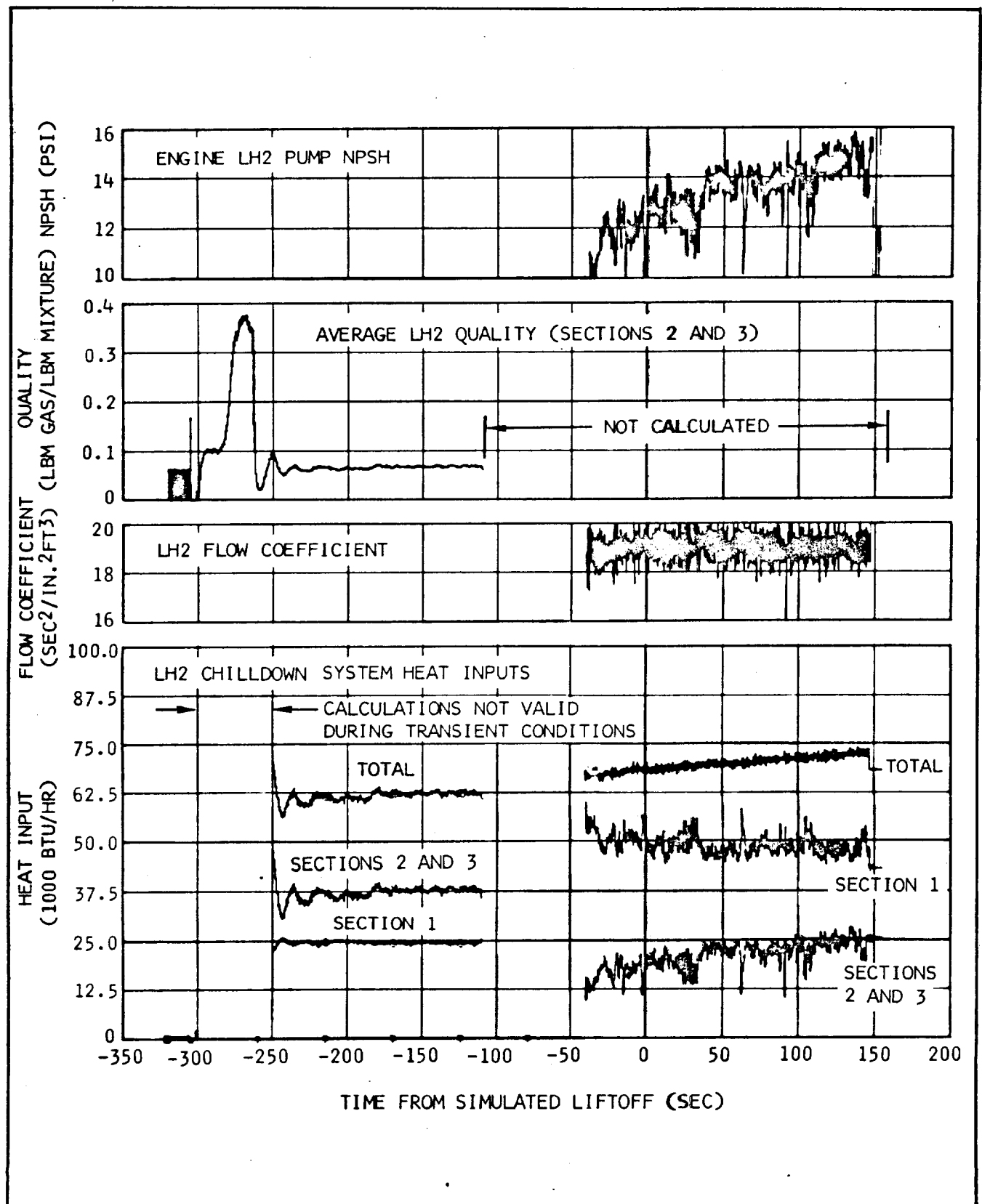


Figure 8-5. LH2 Pump Chilldown Characteristics

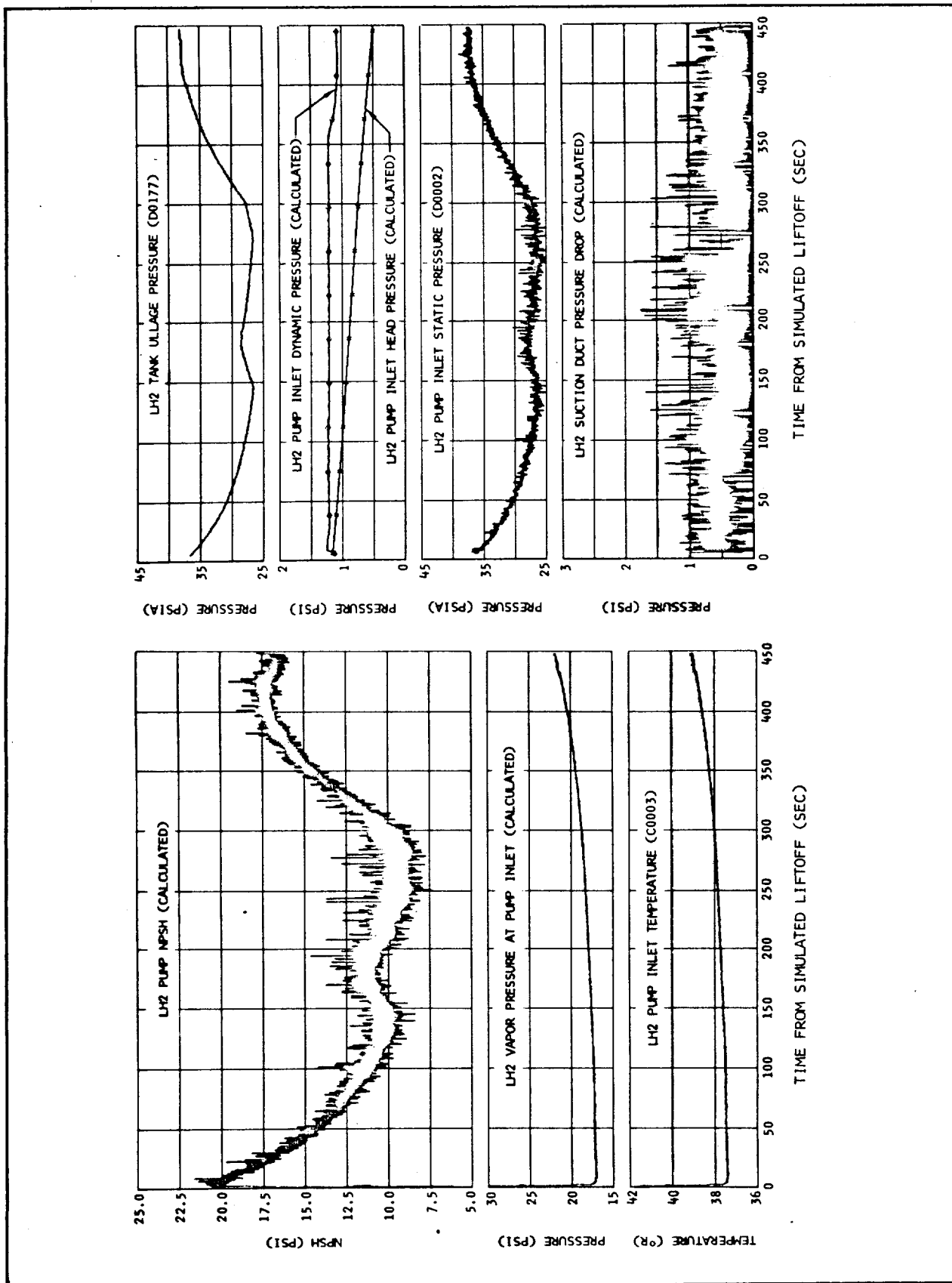


Figure 8-7. LH2 Pump Inlet Conditions

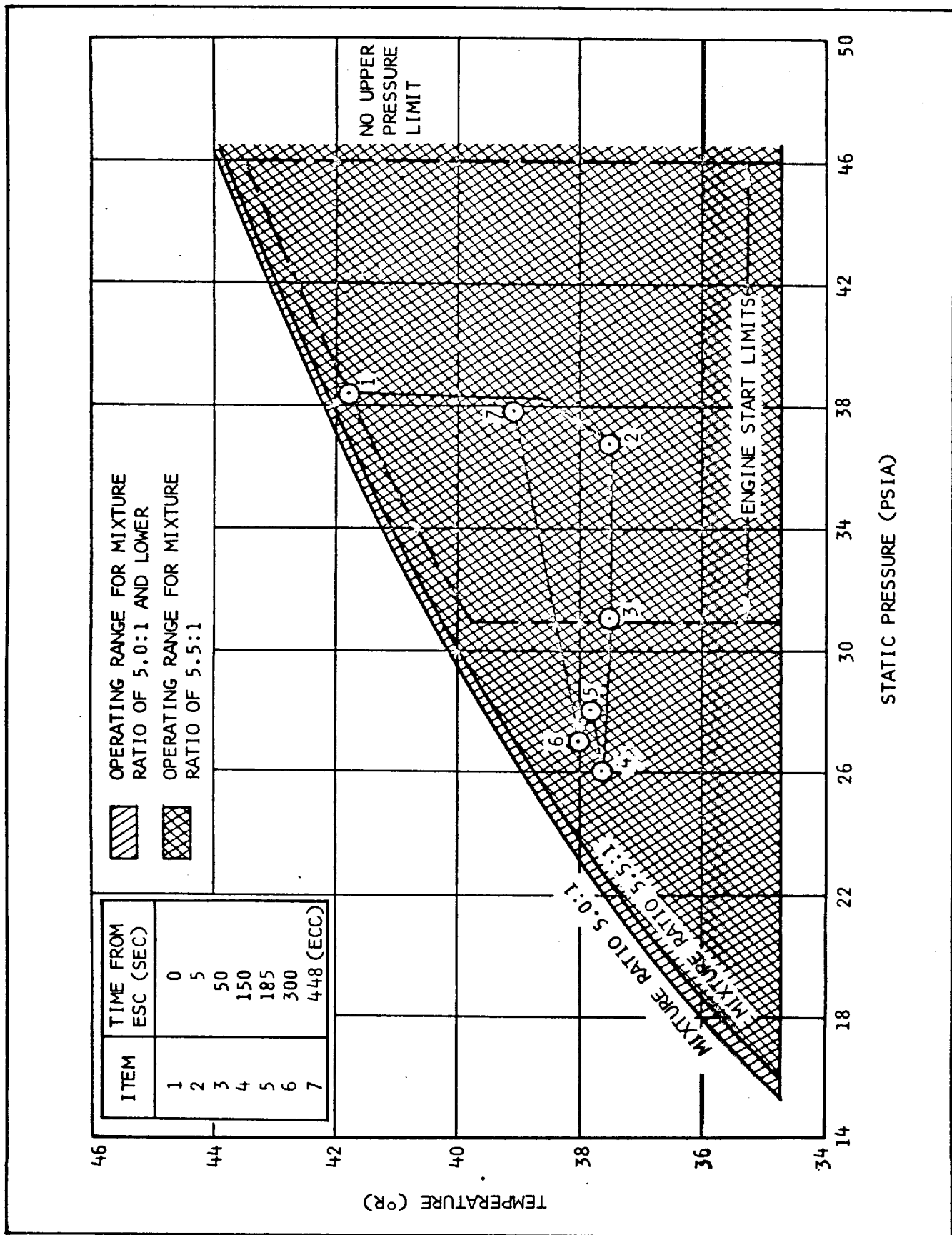


Figure 8-8. LH2 Pump Inlet Conditions During Firing

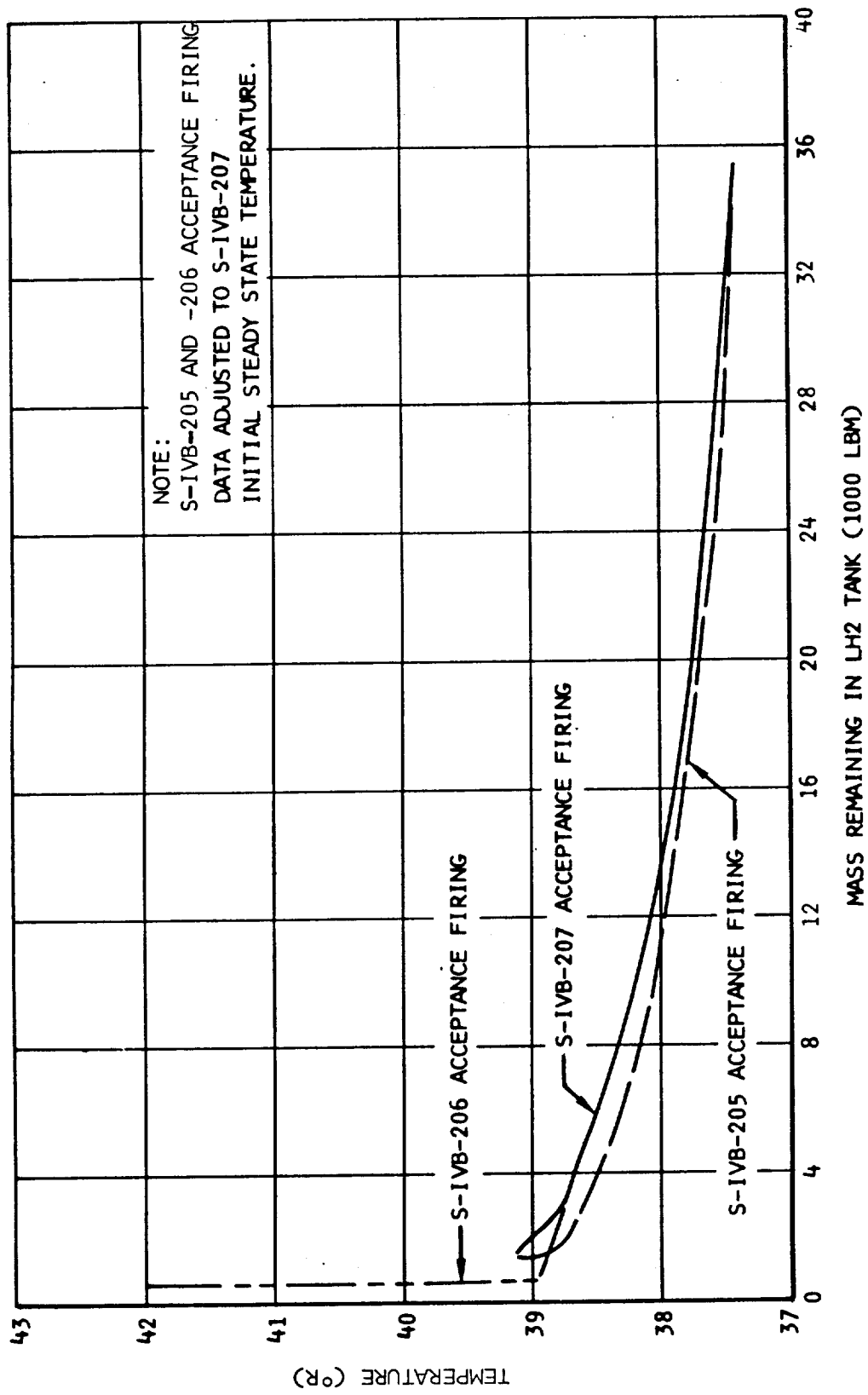


Figure 8-9. Effect of LH2 Mass Level on LH2 Pump Inlet Temperature

SECTION 9

PNEUMATIC CONTROL AND PURGE SYSTEM

9. PNEUMATIC CONTROL AND PURGE SYSTEM

The pneumatic control and purge system (figure 9-1) performed satisfactorily throughout the acceptance firing. The helium supply to the system was adequate for both pneumatic valve control and purging; the regulated pressure was maintained within acceptable limits and all components functioned normally. Data are presented in table 9-1 and figure 9-2.

9.1 Pneumatic Control

All engine and stage pneumatic control valves responded properly throughout the countdown and acceptance firing. The pneumatic control helium regulator operated satisfactorily.

9.2 Ambient Helium Purges

During the acceptance firing, ten purge functions were satisfactorily accomplished. The pneumatic system was isolated from the GSE at $T_0 + 90$ sec; therefore, the purges from the facility supply were discontinued at this time. The purge function characteristics, gas sources, and purging periods are listed in table 9-2.

Throughout the acceptance firing the LOX chilldown motor container pressure was maintained within the design range. This demonstrated satisfactory operation of the ambient helium purge system.

TABLE 9-1
PNEUMATIC CONTROL AND PURGE SYSTEM DATA SUMMARY

PARAMETERS	S-IVB-207	S-IVB-206	S-IVB-205	UNITS
<u>Sphere Conditions</u>				
Pressure at simulated liftoff (T_0)	3,005	3,150	2,830	psia
Pressure at $T_0 + 90$ sec*	3,010	3,135	2,830	psia
Pressure at Engine Start Command	2,989	3,090	2,800	psia
Pressure at Engine Cutoff Command	2,985	3,010	2,700	psia
Temperature at simulated liftoff	480	523	506	deg R
Temperature at $T_0 + 90$ sec*	480	520	504	deg R
Temperature at Engine Start Command	480	517	502	deg R
Temperature at Engine Cutoff Command	487	511	497	deg R
Mass at $T_0 + 90$ sec*	1.10	1.166	0.996	lbm
Mass at Engine Cutoff Command	1.07	1.143	0.968	lbm
Mass usage from $T_0 + 90$ sec* until prevalves opened	0.005	0.006	0.011	lbm
Mass usage during interval required to close LOX and LH2 chilldown shutoff valves	0.025	0.017	0.017	lbm
Mass usage during engine operation	0	0	0	lbm
Total mass usage from $T_0 + 90$ sec* to Engine Cutoff Command	0.03	0.023	0.028	lbm
<u>Regulator Outlet</u>				
Maintained output pressure	540-510	545-520	550-520	psia
System pressure drop during start and cutoff transients	445	470	455	psia
Regulator lockup pressure	600	600	580	psia
<u>LOX Chilldown Motor Container Purge</u>				
Purge pressure range	49-52**	40**	48**	psia

*GSE was isolated at $T_0 + 90$ sec.

**S-IVB-206 pressure switch range was 37 to 40 psia; S-IVB-207 and 205 pressure switch ranges were 49 to 53 psia.

TABLE 9-2
S-IVB-207 STAGE PURGE FUNCTIONS

PURGE FUNCTION	PURGE HELIUM SOURCE			ORIFICE TYPE/SIZE	NOMINAL FLOWRATE
	GROUND PHASE	BOOST	S-IVB FLIGHT PHASE		
LOX tank vent valve	Facility*	**		0.024 in.	65 scfm at 3,100 psig
Engine fuel turbine seal cavity	Stage†	Stage	Stage	++	
Engine LH2 pump seal cavity	Stage	Stage	Stage	++	Total 6.0 scfm at 105-130 psia
Engine LOX pump seal	Stage	Stage	Stage	++	
GG GH2 injector	Stage	Stage	Stage	++	
LOX chilldown pump module	Stage	Stage	Stage	Sintered	950 ±95 scim at 475 psid
LOX fill and drain valve housing	Facility	**		Sintered	15 scim 3,200 psig
LH2 fill and drain	Facility	**		Sintered	15 scim 3,200 psig
LH2 nonpropulsive vent	Facility	**		Sintered	1,728 scim 3,200 psig
LH2 chilldown shutoff valve	Facility	**		Sintered	65 scfm at 3,000 psid

* Facility = GSE console A (DSV-4B-319)

** Purged from facility until GSE isolation at SLO +91 sec

+ Stage = S-IVB regulated pneumatic control supply

++ Common orifice in engine pump purge control module

NOTE: SEE FIGURE 3-1 FOR LEGEND

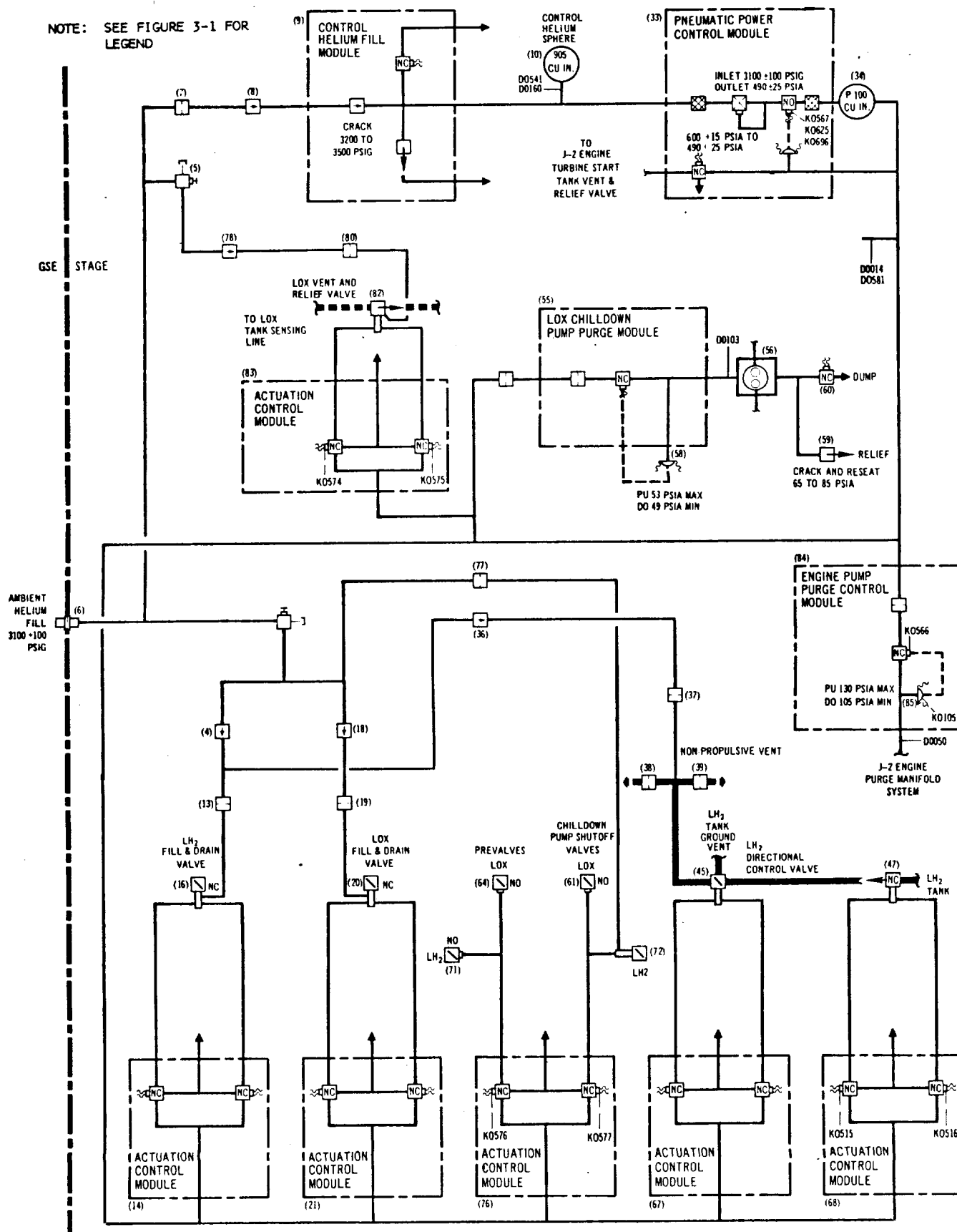


Figure 9-1. Pneumatic Control and Purge System

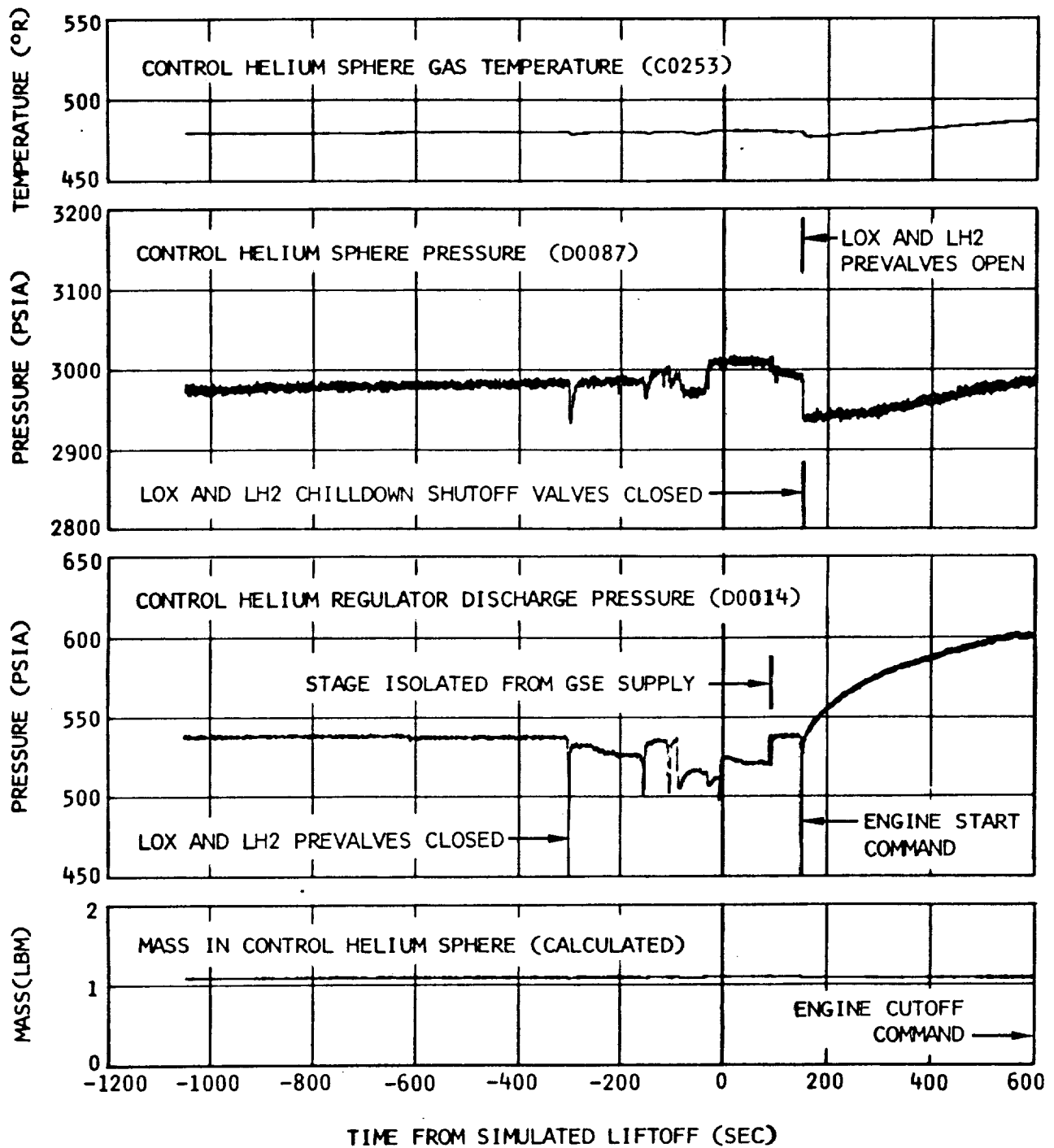


Figure 9-2. Pneumatic Control and Purge System Performance

SECTION 10

PROPELLANT UTILIZATION SYSTEM

10. PROPELLANT UTILIZATION SYSTEM

The propellant utilization (PU) system accomplished all design objectives as listed in DAC Report No. SM-47457A, Saturn S-IVB-207 Stage Acceptance Firing Test Plan.

10.1 PU System Calibration

The nominal pre-acceptance mass sensor calibration was determined from a combination of empirical and theoretical analyses.

The propellant mass at the lower calibration point was determined from the calculated tank volume and predicted propellant density. The corresponding capacitance was determined from the vendor's sensor calibration data and fast drain data from previous acceptance firings.

The propellant mass and its corresponding capacitance at the upper calibration point was determined from the vendor's calibration data and the immersed sensor data from the facilities vehicle.

The LOX and LH2 PU mass sensor calibrations are listed in the following table:

PU MASS SENSORS	CAPACITANCE (pf)	MASS (lbm)	LOCATION
LOX	282.12	1,277	Bottom of inner element
	414.38	195,851	Top of inner element
	412.63	193,273	Full load
LH2	973.96	206	Bottom of inner element
	1,190.37	44,945	Top of inner element
	1,154.00	37,427	Full load

10.2 Propellant Utilization

10.2.1 Propellant Loading

Propellant loading was accomplished automatically by the loading computer. The following tabulation presents propellant loading values at Engine Start Command.

PROPELLANT LOADING	LOX (lbm)	LH2 (lbm)
Desired full load (predicted)	193,273	37,427
Indicated full load (PU reading)	192,813	37,196
Actual full load (flow integral)	194,802	36,714
Difference (indicated less desired)	-460	-231
Difference (actual less desired)	+1,529 (0.8%)	-713 (1.9%)
Difference (indicated less actual)	-1,989 (-1.0%)	+482 (1.3%)

10.2.2 Propellant Mass History

Propellant mass history during the acceptance firing is presented in table 10-1. Results of the flow integral and volumetric methods of mass determination will be used to calibrate the PU system mass sensors to achieve the desired one percent stage loading accuracy for flight. The flow integral method consists of determining the propellant mass flowrates and integrating as a function of time to obtain the total masses consumed during firing.

Flow integral mass values are based on an analysis of propellant flowrates using engine influence equations (computer program AA89), engine flowmeter data (computer program G105-3), and thrust chamber Delta T data (computer program F823-1). The three computer programs were combined into a single set of values by arithmetic averaging.

The initial full load masses are determined by adding final residuals and boiloff to the flow integral values. GH2 pressurant used is also added to the LH2 value. The following tabulation lists total additions to the flow integral for determination of full load.

DESCRIPTION	LOX (lbm)	LH2 (lbm)
Propellant residual	1,920	1,060
Net mass lost through boiloff	0	180
GH2 pressurant used	285	- - -
Total Additions	2,205	1,240

10.2.3 Propellant Residuals

Propellant residuals were computed at Engine Cutoff Command using both the PU mass sensor and point level sensor data in each tank. One level sensor in the LH2 tank (L0002) and two in the LOX tank (L0005, L0004) were activated during the firing and used for the residual computations.

The residuals for L0002, L0004, L0005 were generated using engine flow data to extrapolate from level sensor activation to engine cutoff. The PU system and level sensor masses at engine cutoff are a weighted average of the aforementioned extrapolated residuals. The residual masses at engine cutoff are the best estimate residuals generated by weighted averaging the level sensor and PU mass sensor residuals.

The following table presents a comparison of the propellant residuals determined by the PU system and level sensors.

TIME	LOX (lbm)		RESIDUAL	LH2 (lbm)		RESIDUAL
	PU SYSTEM	LEVEL SENSOR		PU SYSTEM	LEVEL SENSOR	
Level sensor activation L0005 (T_o^* +576.84)	9,703	9,879	1,847			
Level sensor activation L0002 (T_o +583.01)				2,199	2,264	1,067
Level sensor activation L0004 (T_o +598.09)	2,353	2,223	1,927			
Engine cutoff (T_o +598.94)	1,993 <u>+320</u>	1,911 <u>+110</u>	1,920** <u>+104</u>	1,044 <u>+70</u>	1,067 <u>+44</u>	1,060** <u>+37</u>

* T_o - Simulated Liftoff

** Best estimate residuals

10.3 System Operation

10.3.1 PU System Response

Figures 10-1 and 10-2 present the normalized nonlinearity of the LH2 and LOX mass sensors as compared to the flow integral reference. Smooth curves drawn through these plots would represent the mass sensor-to-tank mismatch.

Superimposed on these hypothetically smooth mismatch nonlinearity curves are the manufacturer discontinuities in linearity. The LOX mass sensor has a maximum error of approximately +0.4 percent occurring near the 50 percent level of the tank. The LH2 mass sensor has a maximum error of approximately +0.35 percent near the 25 percent level of the tank.

The S-IVB-207 acceptance firing was the first test of the PU system redesigned slosh filter and reshaped LOX mass sensor. The sensor was redesigned to reduce thrust variations caused by tank-to-sensor mismatch and manufacturing nonlinearities. A reduction in thrust variation was not apparent due to the relatively short period of constant EMR operation after PU valve cutback. The sensor manufacturing nonlinearities were, however, significantly reduced as illustrated by the sensor vendor data shown in figure 10-3. The LOX tank-to-sensor mismatch was also reduced by the LOX sensor modification. Figure 10-4 compares the average LOX tank-to-sensor mismatch from previous acceptance firing results with the predicted and actual S-IVB-207 acceptance firing mismatch.

S-IVB-207 acceptance firing PU valve history predicted a PU valve cutback time of ESC +280 sec (figure 10-5). Actual PU cutback occurred at ESC +330 sec. The actual mean level of valve position after cutback was approximately one degree higher than predicted. The differences between predicted and actual were caused by the following:

DESCRIPTION	CUTBACK TIME DISPERSION (sec)	VALVE POSITION SHIFT (deg)
1. Loading errors	+10.6	0.0
2. Calibration errors	+39.1	+4.2
3. Difference between predicted and actual tank-to-sensor mismatch data	-6.8	+2.0

DESCRIPTION	CUTBACK TIME DISPERSION (sec)	VALVE POSITION SHIFT (deg)
4. Engine performance shift	<u>+9.2</u>	-3.0
5. Open loop flowrate deviation	-2.1	-2.1
Total	+50.0	+1.1

Considering the above factors, predicted cutback time would increase by 50.0 sec and the mean level of the PU valve position after cutback would increase by 1.1 deg. This gives a close comparison between the actual valve response and the reconstructed valve history.

Due to the late PU valve cutback time, the thrust variations during the last 70 sec of burn include the effects of the cutback transient and are larger than the MSFC requirements. The mean slope and maximum zero-to-peak variation in thrust were -75 lbf/sec and 3,500 lbf, respectively.

Loading errors are the difference between desired and actual indicated loads. The loading errors were -460 lbm LOX and -231 lbm LH2. The combined effect of these errors was to increase cutback by 10.6 sec.

Calibration deviations at ESC were +1.02 percent LOX and -1.41 percent LH2 thus causing the initial LOX mass to be overloaded and the initial LH2 mass to be underloaded by the above percentages. Calibration deviations at ECC were +0.09 percent LOX and +0.02 percent LH2. The slope deviations between ESC and ECC were +0.91 percent LOX and -1.43 percent LH2. These slope deviations caused the desired bridge gain ratio (BGR) of 4.8:1.0 to actually be 4.91:1.0. As a result of the change in BGR, the desired EMR of 4.7:1.0 after the transient was actually 4.88:1.0.

The LOX equivalent calibration error between the mass/capacitance end points is +2.34 percent. This LOX equivalent calibration deviation will cause a 39.1 sec increase in cutback time and a +4.2 deg shift in valve position.

The effect of the differences between the average of previous acceptance firings tank-to-sensor mismatch results used for the S-IVB-207 predicted and actual tank-to-sensor mismatch was to decrease cutback time by -6.8 sec and to shift the mean value of valve position by +2.0 deg.

At ESC +120 sec, an engine performance shift occurred which caused the LOX and LH2 flowrates to be lower than predicted (see section 6 for discussion). The lower flowrates caused the PU valve cutback time to occur 9.2 sec later and the mean level of the valve after the cutback transient to be 3.0 deg lower. The above values were obtained by comparing the actual results with a simulation that did not include the engine performance shift.

The effect of the differences between the predicted and actual pump inlet conditions, pressurization rates, and boiloff rates was to decrease cutback time by -2.1 sec and to shift the mean level of valve position after cutback by -2.1 deg.

Figures 10-5 and 10-6 show the predicted and actual mismatch extended to the sensor extremities with the manufacturing nonlinearities removed.

10.3.2 PU Efficiency

LOX propellant depletion extrapolated from propellant mass history rates at cutoff, would have occurred at ESC +451.88 sec with 17.5 lbm of usable LH2 remaining. This is equivalent to a closed loop efficiency of 99.99 percent. Stage propellant consumption rates at engine cutoff, were:

LOX Mass Consumption Rate (\dot{W}_{LOX}) - 368.91 lbm/sec

LH2 Mass Consumption Rate (\dot{W}_{LH2}) - 74.48 lbm/sec.

These values represent the summation of total flow through the engine, boiloff rates, and GH2 pressurant flowrate.

TABLE 10-1
PROPELLANT MASS HISTORY

EVENT	FLOW INTEGRAL MASS (lbm)			PU SYSTEM(1) MASS (lbm)			DEVIATION(2) (lbm)	
	LOX	LH2	TOTAL	LOX	LH2	TOTAL	LOX	LH2
Simulated Liftoff (T_o)	194,802	36,714	231,516	194,125	37,084	231,209	-677	+370
Engine Start Command (ESC) (3) $T_o + 150.863$	194,802	36,714	231,516	194,125	37,084	231,209	-677	+370
PU Valve Cutback ESC +330.0	48,099	10,157	58,256	47,930	10,162	58,092	-169	+5
Engine Cutoff Command (ECC) ESC +448.077	1,920	1,060	2,480	1,993	1,044	3,037	+73	-16

(1) = The total mass in tank as determined by the PU system (corrected for nonlinearity.

(2) = Deviation of the corrected PU system mass from the flow integral mass.

(3) = The masses shown at ESC are considered the same as the masses at SLO.

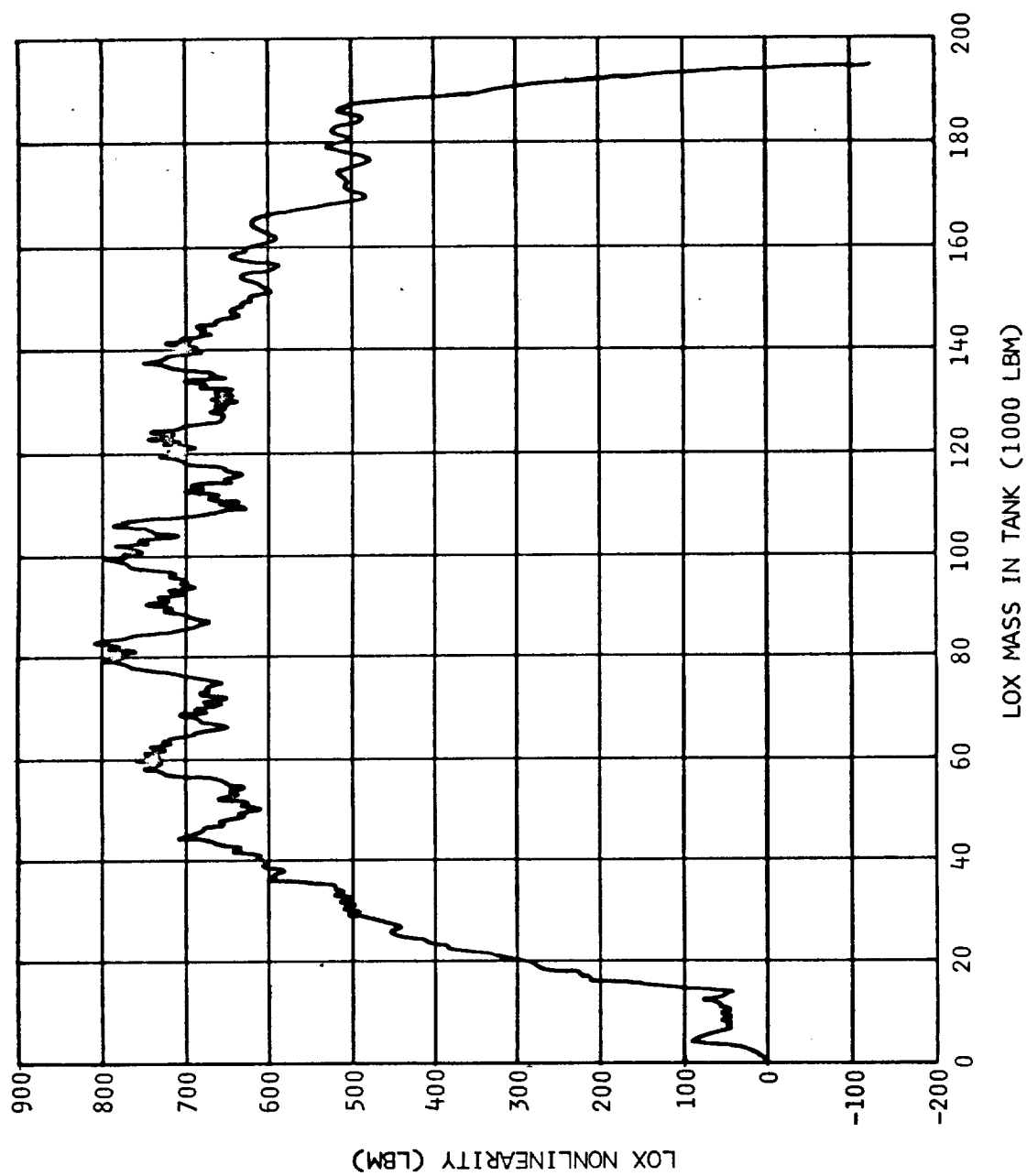


Figure 10-1. Total LOX Nonlinearity

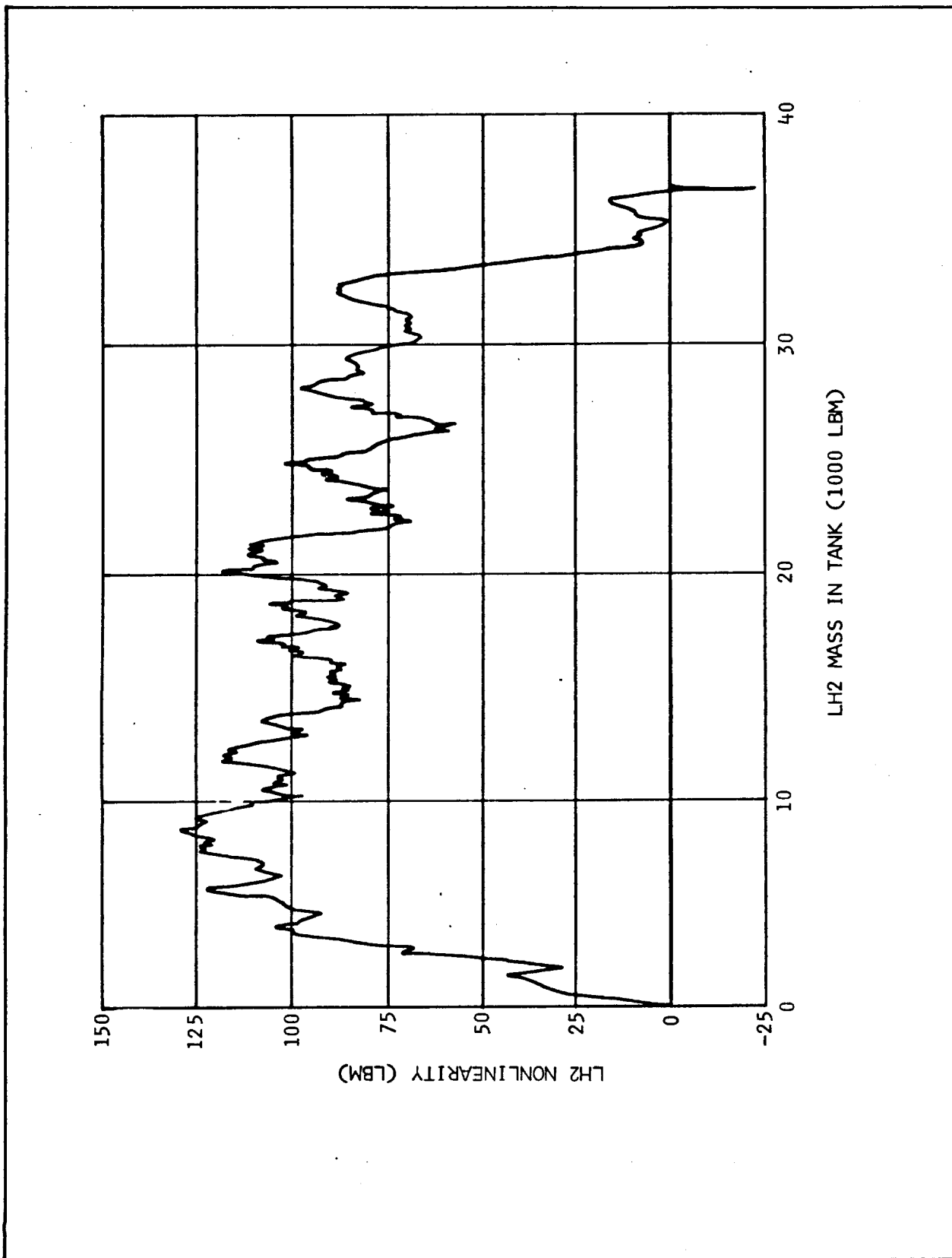


Figure 10-2. Total LH2 Nonlinearity

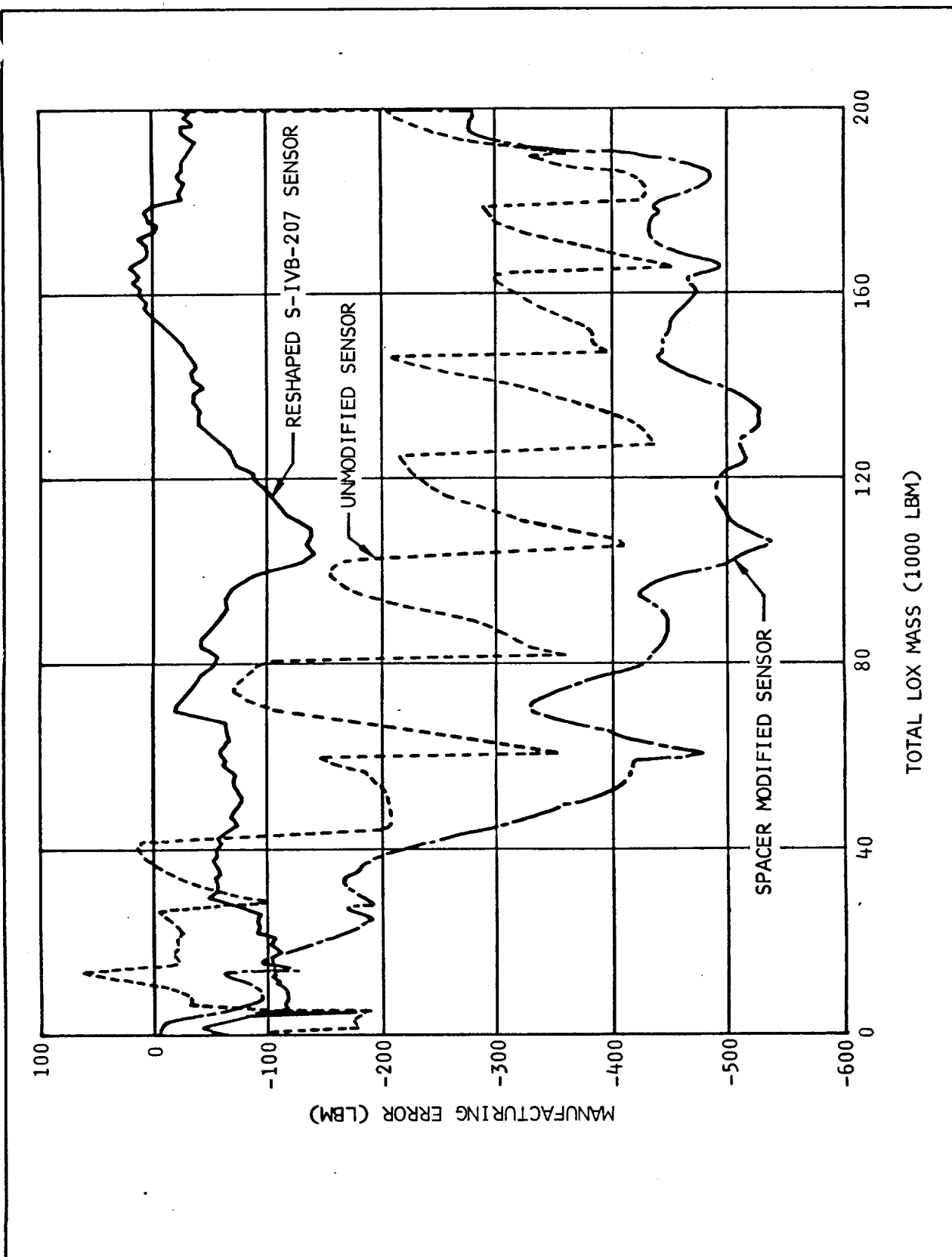


Figure 10-3. LOX Sensor Manufacturing Nonlinearities

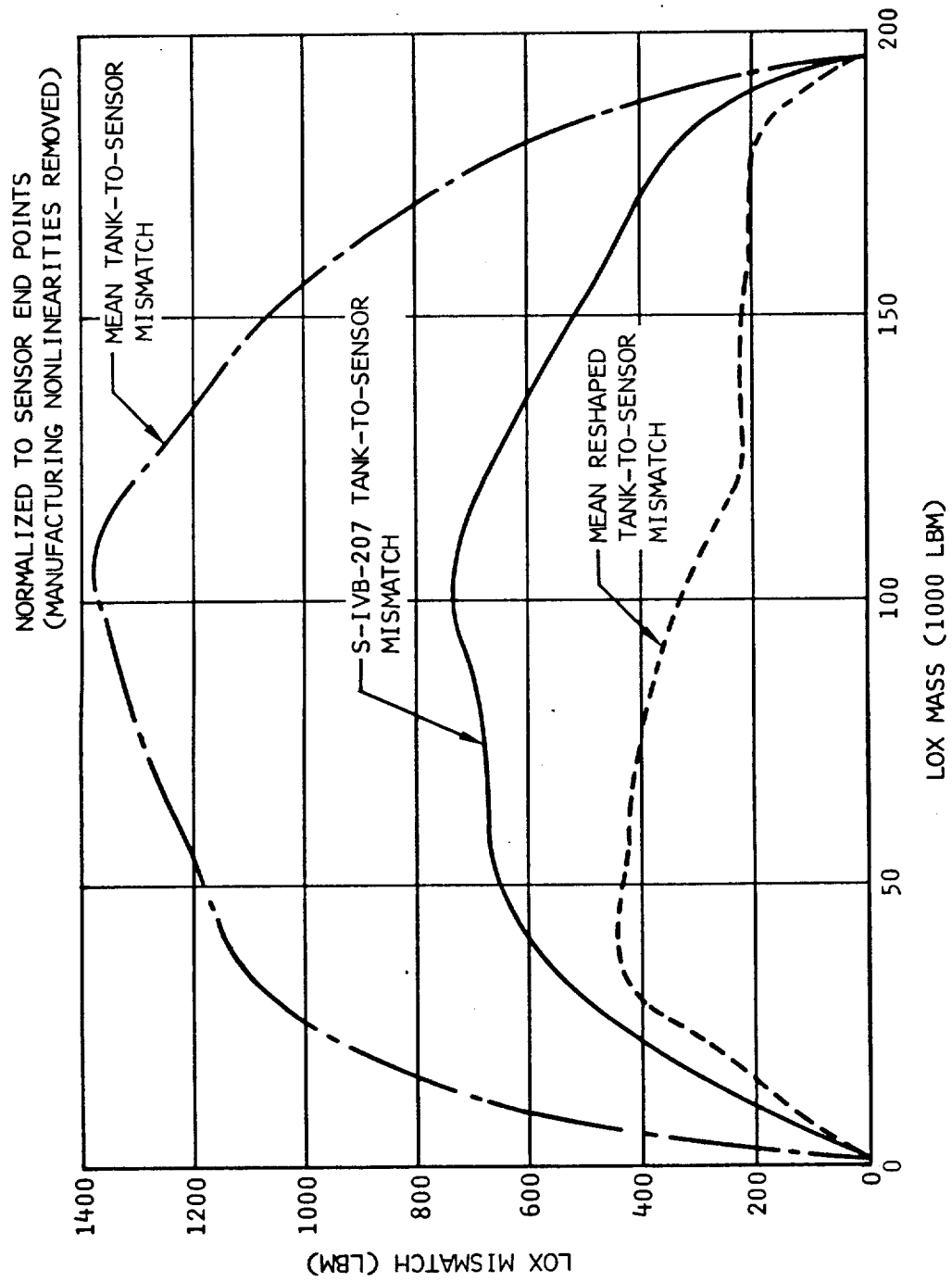


Figure 10-4. LOX Tank-to-Sensor Mismatch

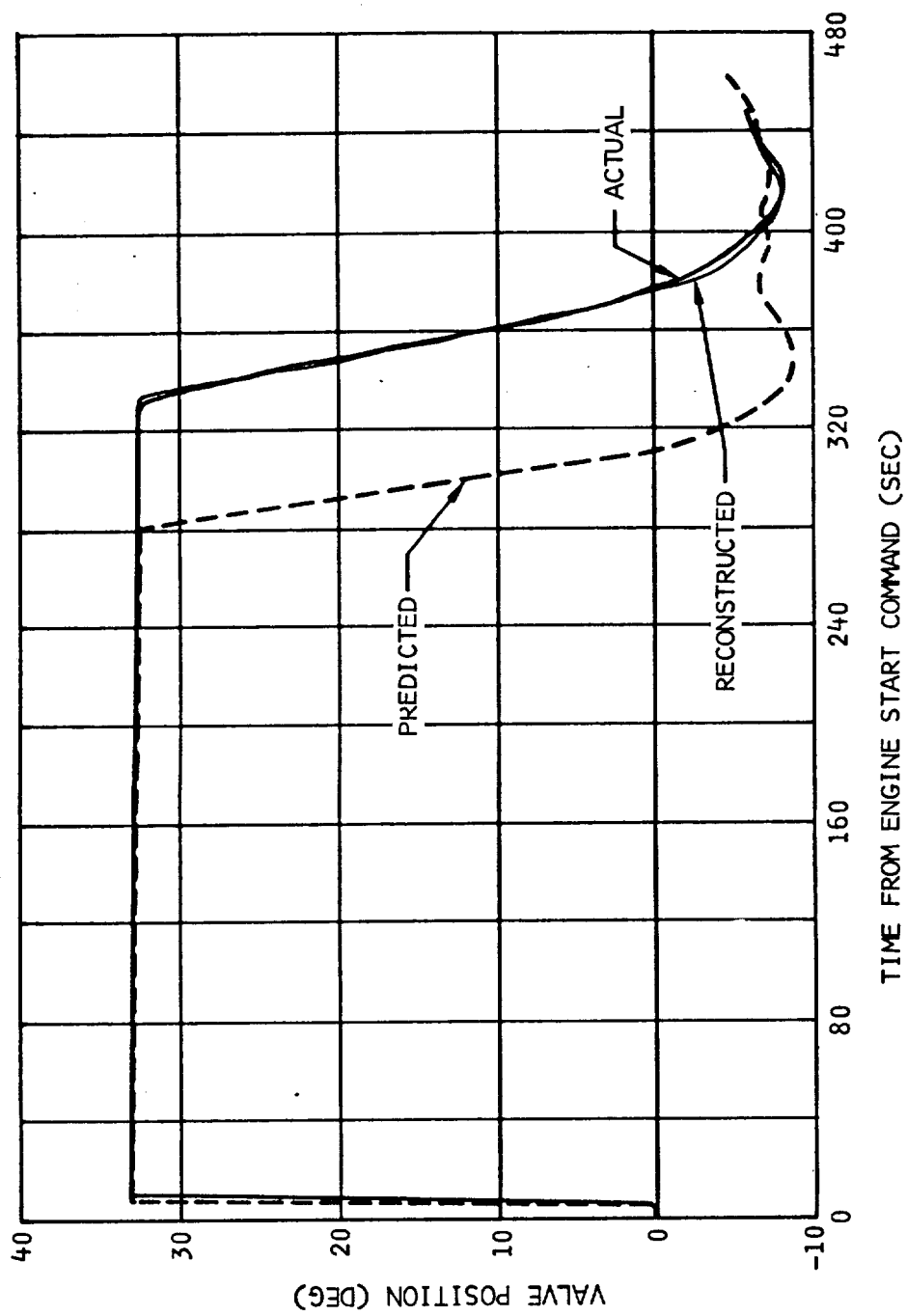


Figure 10-5. PU Valve Position

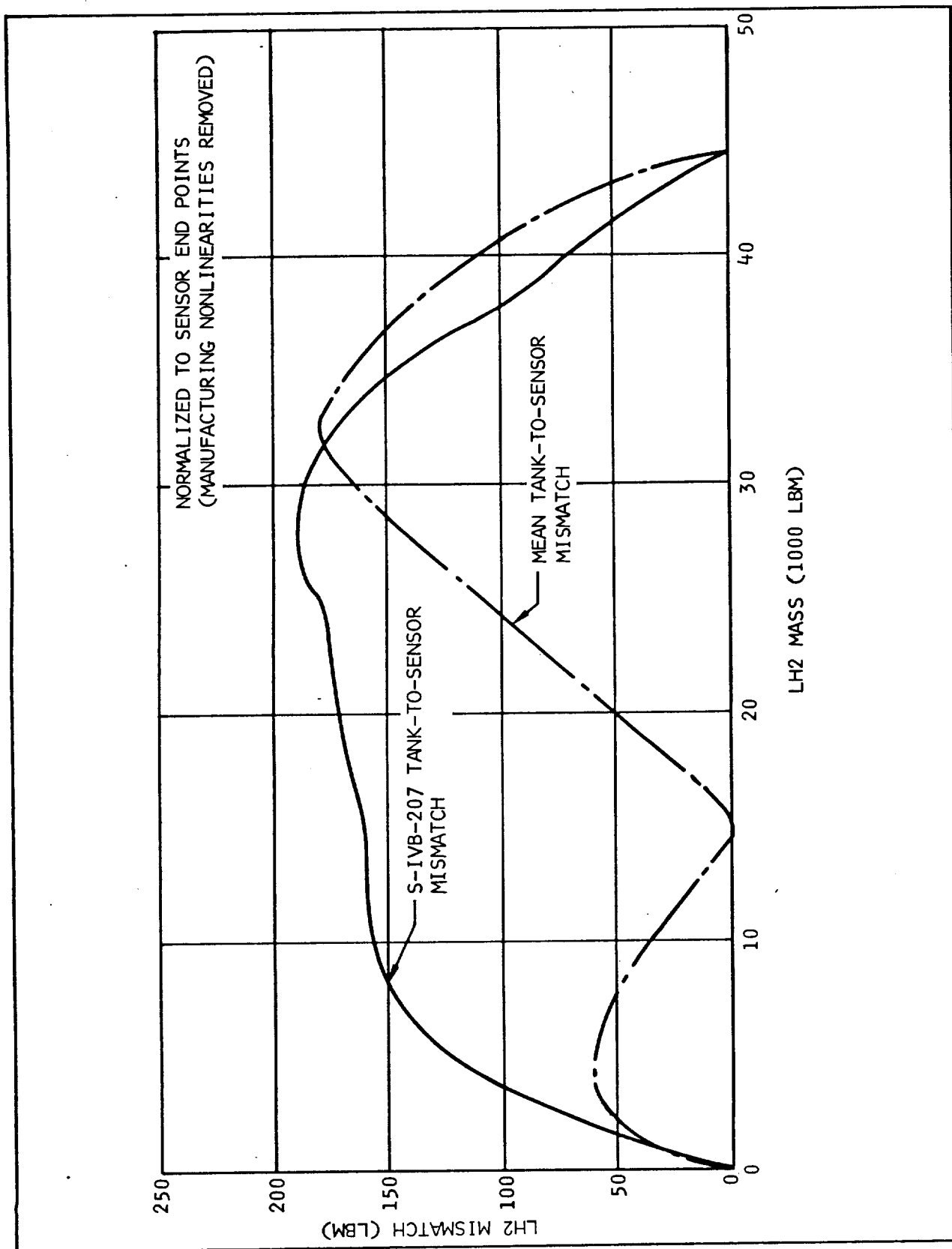


Figure 10-6. LH2 Tank-to-Sensor Mismatch

SECTION 11

DATA ACQUISITION SYSTEM

11. DATA ACQUISITION SYSTEM

The data acquisition system is designed to collect and transmit information describing the stage environment and performance of the stage systems. The measurements which comprise this required information are specified in Douglas Drawing No. 1B43560, Instrumentation Program and Components List (IPCL). The stage data acquisition system performed nominally throughout the acceptance firing. All acceptance criteria were met satisfactorily. A measurement summary is presented in the following table.

Measurement Efficiency	98.3%
Total number of measurements assigned	228
Total number of measurements deleted	56
Total number of active measurements	172
Measurement failures	3
Total successful measurements	169

11.1 Instrumentation System Performance

The instrumentation system performed satisfactorily throughout the acceptance firing. The instrumentation system performance is presented in table 11-1. Measurement discrepancies that occurred during the acceptance firing are listed, with their qualification comments, in table 11-2. The status of the telemetry measurements is tabulated in table 11-3.

The RAC calibration data (T_0 -2,721 sec) verified all active channels were operating prior to the firing.

Comparison of the PCM and hardwire (strip chart, GIS, FM) data in table 11-4 verified the validity of the telemetry data.

11.2 Telemetry System Performance

The telemetry system performance was good. No loss of system synchronization was observed and acceptable data were received from all data channels. The inflight calibration of the Model 270 multiplexers at T_0 +91 sec was verified on all channels.

11.3 RF Subsystem Performance

The RF subsystem performance was normal. Acceptable signal strength was observed at the ground station. A summary of the RF system performance is presented in the following table:

SYSTEM	PCM/FM
RF Power Amplifier Output (Watts) (Minimum Acceptable is 12 Watts)	25.2 W
Deviation (RMS)	30 KC
Ground Station Signal Strength (UV)	10 K
SYSTEM	
Reflected Power (Watts)	0.16 W
VSWR (Maximum Acceptable is 3.1:1)	1.172:1

11.4 Electromagnetic Compatibility

The data acquisition system was electromagnetically compatible with all other stage systems with one exception. Radio frequency interference was observed on the pressure measurement, D0016-424 (refer to table 11-2).

11.5 EDS Measurements

The LH2 and LOX tank ullage emergency detection system (EDS) pressure measurements performed satisfactorily as shown in figure 11-1. The variation between the LOX EDS measurements, which is within instrumentation tolerance, was introduced in the data reduction process.

11.6 Hardwire Data Acquisition System Performance

The ground instrumentation system (GIS) provides a backup and data comparison for certain stage telemetry system parameters in addition to recording measurements from the ground support and facility equipment. The GIS also provides strip charts for redline and cutoff parameter monitoring. The GIS performance during the acceptance firing was satisfactory.

The following table presents the type of recording equipment and the number of channels used during the acceptance firing.

Ground Recorder	Channels Assigned
Beckman 210 Digital Data System	245
Constant Bandwidth FM	53
Wideband FM	6
Strip Charts	35
Total	339

Table 11-5 presents a tabulation of the various types of measurement data recorded and the performance of the system.

11.6.1 Hardwire Measurement Discrepancies

There was one measurement failure and two measurements were classified partially successful yielding an overall hardwire efficiency of 99.2 percent. Measurement discrepancies that occurred during the acceptance firing are listed in table 11-6.

11.6.2 GSE Measurements

Three of the four hardwire chilldown shutoff valve talkback signals were erratic during the acceptance firing. Initially, during critical components cycling prior to initiation of the acceptance firing, the LH2 chilldown shutoff valve closed talkback (K0551) failed. After the valves were cycled several times, measurement K0551 indicated properly but the LOX chilldown shutoff valve open talkback (K0545) failed; however, the test was continued and K0545 picked up eight sec after initiation of LOX tank prepressurization.

TABLE 11-1
INSTRUMENTATION SYSTEM PERFORMANCE SUMMARY

FUNCTION	ASSIGNED PER IP & CL	DELETED	INACTIVE	ACTIVE	DISCREPANCIES	ACCEPTABLE
Temperature	45	13	0	32	1	31
Pressure	56	24	1	31	1	30
Flow	4	0	0	4	0	4
Position	8	5	0	3	0	3
Events	66	8	0	58	0	58
Liquid Level	5	1	0	4	0	4
Volt, Current, Frequency	29	0	0	29	0	29
Miscellaneous	13	4	0	9	0	9
Speed	2	0	0	2	1	1
TOTAL	228	55	1	172	3	169

TABLE 11-2
T/M MEASUREMENT DISCREPANCIES

MEASUREMENT NO.	PARAMETER	REMARKS
C001-401	Temp-Fuel Turbine Inlet	Data invalid after $T_0 + 315$ sec when the data became noisy and increased to the 100% level. After engine cutoff, the data returned to scale; however, the data lagged data produced by C0755 (the comparable hardware measurement). The transducer has been rejected per FARR A218805 and it will be replaced prior to stage shipment.
D0016-424	Press-Cold Helium Sphere	Trend only data; data level was approximately 6% low. The transducer used for this measurement is the 1B40242 strain gage type which has been susceptible to the RFI environment encountered during previous acceptance firings. ECP 7518 revision 1 has been approved to incorporate additional RFI filtering in this transducer on S-IVB-213, -216, -507 and -515. Corrective action on the S-IVB-207 stage is not anticipated since the flight configuration (mated upper stages) provides adequate shielding during flight.
T0001-401	Speed - Oxidizer Pump	Trend only data; data level was approximately 400 rpm low. Post firing checks showed that the ac to dc converter filter rolloff characteristic had changed. The converter was rejected per FARR A218825 and will be replaced prior to stage shipment.

TABLE 11-3 (Sheet 1 of 6)
T/M MEASUREMENT STATUS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REMARKS
VXC0007-401	DP1B0-17L05	Temp. - Engine Control Helium	Open - S/C 1195A requirement for T/M disconnect and H/W recording.
VC0050-401	CP1B0-11-03 DP1B0-11-03	Temp. - Hydr. Pump Inlet Oil	Open - T/M disconnect DAC requirement for H/W recording and redline cutoff.
C0102-411	DP1B0-02-05	Temp. - Fwd. Battery No. 1	Simulated heat sink - primary batteries not used for acceptance firing.
C0103-411	DP1B0-02-06	Temp. - Fwd. Battery No. 2	Same as C0102-411.
C0104-404	DP1B0-11-10	Temp. - Aft Battery No. 1	Same as C0102-411.
C0105-404	DP1B0-14-10	Temp. - Aft Battery No. 2	Same as C0102-411.
C0166-414	DP1B0-20L01	Temp. He Sphere Gas Mod 1 (APS)	Simulated - APS not installed for acceptance firing.
C0167-415	DP1B0-20L02	Temp. He Sphere Gas Mod 2 (APS)	Same as C0166-414.
XC0168-414	CP1B0-11-04 DP1B0-11-04	Temp. Oxid Tank Outlet Mod 1 (APS)	Same as C0166-414.
XC0169-415	CP1B0-11-05 DP1B0-11-05	Temp. Oxid Tank Outlet Mod 2 (APS)	Same as C0166-414.

TABLE 11-3 (Sheet 2 of 6)
T/M MEASUREMENT STATUS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REMARKS
XC0170-414	CPIB0-11-06 DPIB0-11-06	Temp. Fuel Tank Outlet Mod 1 (APS)	Same as C0166-414.
XC0171-415	CPIB0-11-07 DPIB0-11-07	Temp. Fuel Tank Outlet Mod 2 (APS)	Same as C0166-414.
C0200-401	DPIB0-18L06	Temp. Fuel Injection	Open - S/C 1195A requirement for T/M disconnect and H/W recording.
VXD0041-403	CPIB0-13-05 DPIB0-13-05	Press. Hydraulic System	Same as C0200-401.
VXD0042-403	DPIB0-06-07	Press. Reservoir Oil	Same as C0200-401
VD0054-410	DPIB0-01-08	Press. Fuel Tank Inlet	Open - Part not available. Transducer shortage.
VD0055-424	DPIB0-06-09-00	Press. - Oxidizer Tank Inlet	Substitute transducer used.
VXD0063-414	DPIB0-07-02	Press. Fuel Supply Manifold Mod 1 (APS)	Simulated - APS not installed for acceptance firing.
VXD0064-414	CPIB0-13-07 DPIB0-13-07	Press. He Regulator Inlet Mod 1 (APS)	Same as VXD0063-414.
VD0065-414	CPIB0-13-08 DPIB0-13-08	Press. He Regulator Outlet Mod 1 (APS)	Same as VXD0063-414.

TABLE 11-3 (Sheet 3 of 6)
T/M MEASUREMENT STATUS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REMARKS
VXD0066-415	DPIB0-07-03	Press. Oxid Supply Manifold Mod 2 (APS)	Same as VXD0063-414.
VXD0067-415	DPIB0-07-04	Press. Fuel Supply Manifold Mod 2 (APS)	Same as VXD0063-414.
VXD0068-415	CPIB0-13-09 DPIB0-13-09	Press. He Regulator Inlet Mod 2 (APS)	Same as VXD0063-414.
VD0069-415	CPIB0-13-10 DPIB0-13-10	Press. He Regulator Outlet Mod 2 (APS)	Same as VXD0063-414.
VXD0078-414	CPIB0-17	Press. Attitude Control Chamber 1-1	Same as VXD0063-414.
VXD0079-414	CPIB0-18	Press. Attitude Control Chamber 1-2	Same as VXD0063-414.
VXD0080-414	CPIB0-19	Press. Attitude Control Chamber 1-3	Same as VXD0063-414.
VXD0081-415	CPIB0-20	Press. Attitude Control Chamber 2-1	Same as VXD0063-414.
VXD0082-415	CPIB0-21	Press. Attitude Control Chamber 2-2	Same as VXD0063-414.
VXD0083-415	CPIB0-22	Press. Attitude Control Chamber 2-3	Same as VXD0063-414.

TABLE 11-3 (Sheet 4 of 6)
T/M MEASUREMENT STATUS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REMARKS
VXD0084-414	DPLB0-07-05	Press. Oxid Supply Manifold Mod 1 (APS)	Same as VXD0063-414.
VXD0089-414	DPLB0-07-07	Press. Fuel Tank Ullage Mod 1 (APS)	Same as VXD0063-414.
VXD0090-414	DPLB0-07-08	Press. Oxid Tank Ullage Mod 2 (APS)	Same as VXD0063-414.
VXD0091-415	DPLB0-07-09	Press. Fuel Tank Ullage Mod 2 (APS)	Same as VXD0063-414.
VXD0092-415	DPLB0-07-10	Press. Oxid Tank Ullage Mod 2 (APS)	Same as VXD0063-414.
D0093-414	DPLB0-08-01	Press. Fuel Tank Outlet Mod 1 (A's)	Same as VXD0063-414.
D0094-414	DPLB0-08-02	Press. Oxid Tank Outlet Mod 1 (APS)	Same as VXD0063-414.
D0095-415	DPLB0-08-03	Press. Oxid Tank Outlet Mod 2 (APS)	Same as VXD0063-414.
D0096-415	DPLB0-08-04	Press. Fuel Tank Outlet Mod 2 (APS)	Same as VXD0063-414.
G0003-401	CPLB0-23-03 DPLB0-23-03	Position Main LOX Valve	Simulated - S/C 1195A requirement for T/M disconnect and hardware record.

TABLE 11-3 (Sheet 5 of 6)
T/M MEASUREMENT STATUS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REMARKS
G0004-401	CPIB0-23-04 DPIB0-23-04	Position Main LH2 Valve	Same as G0003-401.
G0005-401	DPIB0-08-09	Position Gas Generator Valve	Same as G0003-401.
G0008-401	CPIB0-23-05 DPIB0-23-05	Position LOX Turbine Bypass Valve	Same as G0003-401.
G0009-401	DPIB0-08-10	Position GH2 Start Tank Valve	Same as G0003-401.
K0020-401	CPIB0-09R01N10	Event ASI LOX Valves OPEN	Open - Switched from T/M to computer for stage control by Flight Measurement Enable Command.
K0116-401	CPIB0-09R02N10	Event Gas Generator Valve Closed	Same as K0020-401.
K0119-401	CPIB0-09R03N06	Event Main LH2 Valve Closed	Same as K0020-401.
K0121-401	CPIB0-09R03N08	Event. Main LOX Valve Closed	Same as K0020-401.
K0123-401	CPIB0-09R03N10	Event. Start Tank Discharge Valve	Same as K0020-401.
K0126-401	CPIB0-09R04N01 DPIB0-09-04Y01	Event. LOX Bleed Valve Closed	Same as K0020-401.
K0127-401	CPIB0-09R04N02 DPIB0-09-04Y02	Event. LH2 Bleed Valve Closed	Same as K0020-401.

TABLE 11-3 (Sheet 6 of 6)
T/M MEASUREMENT STATUS

MEASUREMENT NO.	T/M CHANNEL NO.	PARAMETER	REMARKS
K0128-404	DP1B0-22	Event Switch Selector	Same as K0020-401.
VXL0007-403	CP1B0-11-08 DP1B0-11-08	Level, Reservoir Oil	Simulated - S/C 1195A requirement for T/M disconnect, hardware recording, and redline.
VXN0037-414	CP1B0-23-07 DP1B0-23-07	Misc. Quantity Oxid Tank Mod 1 (APS)	Simulated - APS not installed for acceptance firing.
VXN0038-415	CP1B0-23-08 DP1B0-23-08	Misc. Quantity Oxid Tank Mod 2 (APS)	Same as VXN0037-414.
VXN0039-414	CP1B0-23-09 DP1B0-23-10	Misc. Quantity Fuel Tank Mod 1 (APS)	Same as VXN0037-414.
VXN0040-415	CP1B0-23-10 DP1B0-23-10	Misc. Quantity Fuel Tank Mod 2 (APS)	Same as VXN0037-414.

TABLE 11-4 (Sheet 1 of 4)
TELEMETRY TO HARDWARE DATA COMPARISON (T₀ +213 SEC)

PARAMETER	T/M		H/W			
	NMN	PCM	NMN	GIS	S/C	F/M
Temp - LH2 Turbine Inlet	C0001	1705	C0755	1704	---	1730
Temp - LH2 Pump Inlet	C0003	37.5	C0658	37.5	37.4	37.4
Temp - LOX Pump Inlet	C0004	164.8	C0659	164.8	165.5	165.3
Temp - GH2 Start Bottle	C0006	219	C0649	224	224	---
Temp - Electrical Control Ass'y	C0011	509	C0657	509	---	---
Temp - LOX Tank He Inlet	C0016	377	C0662	384	---	---
Temp - LOX Pump Discharge	C0133	169.7	C0648	169.8	---	170.2
Temp - LH2 Pump Discharge	C0134	51.4	C0644	51.2	---	51.6
Temp - Thrust Chamber Jacket	C0199	142	C0645*	160	161.5	---
Temp - Cold He Sphere No. 4	C0210	33.0	C0661	32.7	31.6	---
Press - Thrust Chamber	D0001	771	D0524	770	775	765
Press - LH2 Pump Inlet	D0002	29.5	D0536	28.7	28.7	29.7
Press - LOX Pump Inlet	D0003	41.5	D0537	40.7	40.7	40

*The temperature patch for C0645 was not coated with thermal conductive grease; therefore, it was insulated from the chamber jacket.

TABLE 11-4 (Sheet 2 of 4)
TELEMETRY TO HARDWARE DATA COMPARISON (T₀ +213 SEC)

PARAMETER	T/M		H/W			
	NMN	PCM	NMN	GIS	S/C	F/M
Press - Main LH2 Injector	D0004	876	D0518	860	---	865
Press - LH2 Pump Discharge	D0008	1187	D0516	1205	---	1215
Press - LOX Pump Discharge	D0009	1062	D0522	1034	---	1050
Press - GG Chamber	D0010	658	D0530	663	---	665
Press - Cont He Reg Discharge	D0014	558	D0581	566	560	---
Press - Cold He Sphere	D0016	1835*	D0542	2054	2045	---
Press - GH2 Start Bottle	D0017	1163	D0525	1177	1166	1177
Press - Engine Reg Outlet	D0018	411	D0535	413	411	---
Press - Cont He Supply D19	D0019	2533	D0534	2600	2600	---
Press - He (Amb) Sphere	D0160	2943	D0541	2972	2950	---
Press - LOX Tank Ullage - EDS 1	D0177	30.0	D0539	30.6	30.7	---
Press - LOX Tank Ullage - EDS 2	D0178	30.2	D0539	30.6	30.7	---
Press - LH2 Tank Ullage - EDS 1	D0179	38.2	D0540	39.2	38.2	---
Press - LH2 Tank Ullage - EDS 2	D0180	38.8	D0540	39.2	38.2	---

*This discrepancy is caused by the pressure transducer being susceptible to RFI (refer to table 11-2).

TABLE 11-4 (Sheet 3 of 4)
TELEMETRY TO HARDWARE DATA COMPARISON (T₀ +213 SEC)

PARAMETER	T/M		H/W			
	NMN	PCM	NMN	GIS	S/C	F/M
Press - Common Bulkhead Int	D0208	-0.1	D0545	+0.1	+0.1	---
Flowrate - LOX	F0001	2874	F0506	2843	---	2848
Flowrate - LH2	F0002	7806	F0507	7763	---	7776
*Position - Pitch Actuator	G0001	-0.15	G0504	---	0.0	-0.3
*Position - Yaw Actuator	G0002	0.15	G0505	---	0.05	0.2
Position - PU Valve	G0010	0.13	G0503	0.13	0.125	0.2
Voltage - Engine Control Bus	M0006	30.0	M0514	29.8	29.6	30.0
Voltage - Engine Ignition Bus	M0007	30.1	M0515	30.1	29.8	---
Voltage - Aft Battery 1	M0014	30.0	M0541	29.4	---	30.0
Voltage - Aft Battery 2	M0015	59.1	M0540	58.7	58.8	---
Voltage - Fwd Battery 1	M0016	30.4	M0543	30.5	---	30.3
Voltage - Fwd Battery 2	M0018	29.4	M0542	29.2	---	29.6
Current - Fwd Battery 1	M0019	11.0	M0536	15.0	---	15
Current - Fwd Battery 2	M0020	4.7	M0537	4.3	---	---

*Compared at T₀ +218 sec.

TABLE 11-4 (Sheet 4 of 4)
TELEMETRY TO HARDWARE DATA COMPARISON (T₀ +213 SEC)

PARAMETER	T/M		H/W			
	NMN	PCM	NMN	GIS	S/C	F/M
Current - Aft Battery 1	M0021	14	M0534	15.0	---	15
Current - Aft Battery 2	M0022	24.0	M0535	25.0	24	25.0
Speed - LOX Pump	T0001	8098*	T0502	8532	---	8519
Speed - LH2 Pump	T0002	26552	T0503	26650	---	26700

*The signal conditioning module for T0001 has been rejected and is to be replaced (refer to table 11-2).

TABLE 11-5
HARDWIRE DATA ACQUISITION SYSTEM

MEASUREMENT TYPE	RECORDED	FAILED	PARTIALLY SUCCESSFUL	SUCCESSFUL (%)
Pressure	108	0	1	99
Temperature	51	0	0	100
Flow	4	0	0	100
Position	19	0	0	100
Voltage/Current	38	0	0	100
Events/Switches	102	1	0	99
Speed	2	0	0	100
Level	3	0	0	100
Vibration	4	0	1	87.5
Miscellaneous	8	0	0	100
TOTALS	339	1	2	99.2

TABLE 11-6
HARDWIRE MEASUREMENT DISCREPANCIES

MEASUREMENT NO.	PARAMETER	REMARKS
K3750-B03	Event, Sensor No. 1 Valve Complex GH2 Detection System	Measurement failed to produce valid data during the acceptance firing. The cause of the failure is unknown and failure analysis could not be accomplished since the system was removed before analysis was initiated.
D0514-401	Pressure-Augmented Spark Igniter Chamber (FM and Digital)	Valid data were produced by this measurement until $T_0 + 565$ sec after which the measurement failed to respond to measured media pressure fluctuations. It is suspected that the transducer's sense line froze during the firing. Postfiring checks showed that the measurement had returned to normal operation since correct ambient pressure was indicated and it responded correctly to CAL commands.
E0556-401	Vibration-Fuel Pump Radial	This measurement was classified partially successfully since dc shifts were exhibited on the data. Transient spikes of approximately 100 g at 6 kc drove the associated amplifier into saturation. Investigation revealed that Rocketdyne experienced dc shifts from like measurements during engine development. Rocketdyne corrected the problem by adding 10kc filters to the amplifier inputs. The data are invalid only during the dc shifts.

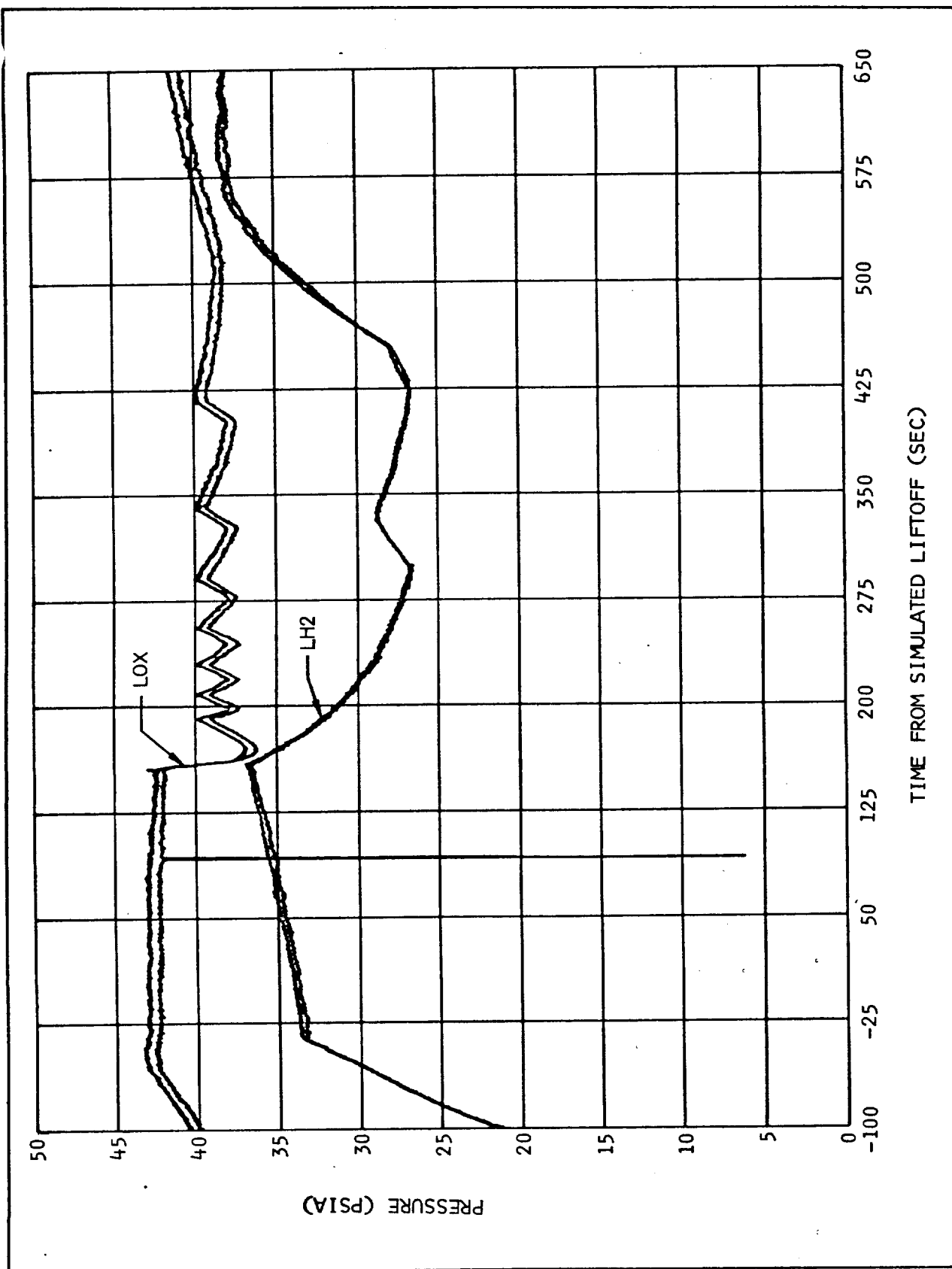


Figure 11-1. EDS Pressure Measurements

SECTION 12

ELECTRICAL POWER & CONTROL SYSTEMS

12. ELECTRICAL POWER AND CONTROL SYSTEMS

12.1 Electrical Control System

All control system events that function as a direct result of a switch selector command performed satisfactorily as shown in the sequence of events (section 5). The system performance of non-programmed events is presented in the following paragraphs.

12.1.1 J-2 Engine Control System

All event measurements verified that the engine control system responded properly to the engine start and cutoff commands. The Engine Start Command was given by the switch selector 150.859 sec after simulated liftoff. Engine cutoff was initiated at 598.940 sec. The total engine burn time was 448.081 sec.

The engine cutoff signal was non-programmed and was initiated by the PU processor which indicated that a 1 percent LOX level had been attained. The cutoff sent a signal to the preclude delay timer. The timer output occurred 430 ms later, within specified limits (425 ± 25 ms). The main LOX and LH2 valves had closed prior to timer output.

12.1.2 Range Safety System

During the engine burn phase, the range safety system was employed for verification of performance integrity. Evaluation of the data verified that the system performed satisfactorily.

12.1.3 Control Pressure Switches

A review of the event and pressure measurements verified that each control item functioned properly. Each pressure switch and associated measurements were evaluated and a description of their performance is presented in the following paragraphs.

K0102 LOX Prepress Flight Switch - Energized

D0179, D0180 Oxid Tank Ullage EDS 1 and 2 Pressure

The measurements verified the satisfactory operation of the pressure switch. The pressure limits of the switch are 37-40.8 psia.

*(K0611) Fuel Tank Flight Control Switch - Energized
(K0524) Fuel Tank Control Valve Solenoid - Energized
D0177, D0178 Fuel Tank Ullage EDS 1 and 2 Pressure

The measurements verified that the pressure switch functioned properly. The pressure limits of the switch are 26.5 - 29.5 psia. The solenoid valve operated properly during the period the first burn relay was activated.

K0105 Engine Pump Purge Control Regulated Back-up Switch De-energized.
(K0566) Engine Pump Purge Control Module Solenoid Valve Energized.
D0050 Engine Pump Purge Regulator Pressure

The measurements verified that the pressure switch was de-energized throughout the firing and the pressure did not attain the actuation pressure of 130 psia.

K0131 LOX Chilloverdown Purge Switch De-energized
(K0565) LOX Pump Purge Control Motor Valve - Energized
D0103 He to LOX Motor Control Pressure

The measurements verified the proper operation of the pressure switch. The pressure limits of the switch are 49-54 psia.

K0156 LOX Tank Regulator Back-up Pressure Switch - Energized
D0225 Pressure - Cold Helium Control Valve Inlet

The measurements verified that the switch was de-energized during the firing and the pressure did not attain the actuation pressure of 465 psia.

12.1.4 Vent Valves

The LOX and LH2 vent valves are commanded open and close by GSE, bypassing the switch selector. The vent valves responded to these commands. Measurements analyzed and a description of their performance is presented in the following paragraphs.

K0001 (K0532) Fuel Tank Vent Valve Closed
K0017 (K0542) Fuel Tank Vent Valve Open

* Hardwire measurement are in parentheses

The Fuel Tank Vent Valve Closed indication chattered 44 times beginning approximately 407.916 sec after engine start. The chatter was on the digital events recorder data via hardwire measurement. The corresponding flight measurement did not verify this chatter due to a slower sample rate. The chatter occurred because the tank pressure was at the relief actuation pressure of the pressure switch, (39 psia). The valve finally remained in the open position indicating relief venting.

K0002 *(K0533) LOX Tank Vent Valve Closed

K0016 (K0543) LOX Tank Vent Valve Open

The LOX vent valve performed satisfactorily.

(K0562) LH2 Tank Directional Vent Valve for In-Flight Position

K0113 LH2 Tank Directional Vent Valve C - Closed

K0114 LH2 Tank Directional Vent Valve D - Closed

(K0561) LH2 Tank Directional Vent Valve - Ground Position

The measurements verified that the ground position indication chattered 300 times over a period of 74.386 sec just after loading of the LH2 tank. There was no indication of chatter during the remainder of the firing.

12.1.5 Chiltdown Shutoff Valves

(K0551) LH2 Chiltdown Shutoff Valve Closed

(K0552) LOX Chiltdown Shutoff Valve Closed

(K0544) LH2 Chiltdown Shutoff Valve Open

(K0545) LOX Chiltdown Shutoff Valve Open

(K0577) LH2 + LOX Chiltdown Shutoff Valve Closed - Energized

During critical components cycling, chiltdown shutoff valve talkback signals were erratic. Initially, the LH2 chiltdown shutoff valve closed talkback (K0551) failed. Manual control was activated and the chiltdown shutoff valves were cycled several times. This action corrected the LH2 chiltdown shutoff valve closed talkback (K0551) problem but resulted in failure of the LOX chiltdown shutoff valve open talkback (K0545); however, the test was continued into terminal count and at eight seconds after initiation of LOX tank prepressurization the LOX chiltdown shutoff valve open talkback (K0545) picked up.

* Hardwire measurement are in parentheses

Measurement K0544 failed to indicate that the valve was fully open following the initiation of the open command. The valve indication did not pickup until just prior to the issuance of the close command. The closed indication was received as expected. The LOX chilldown shutoff valve performed satisfactorily after simulated liftoff.

12.1.6 Fill and Drain Valves

Prior to simulated liftoff the fill and drain valves were commanded closed through the umbilical. These valves remained closed throughout the acceptance firing. After firing, the valves were opened to drain the remaining propellants. The data review of the following measurements verified that the valves performed satisfactorily.

K0003 *(K0554) Fuel Fill and Drain Valve Closed
K0019 (K0546) Fuel Fill and Drain Valve Open
K0004 (K0553) LOX Fill and Drain Valve Closed
K0018 (K0547) LOX Fill and Drain Valve Open

12.1.7 Depletion Sensors

(K0597) LH2 Depletion Sensor No. 1 Wet
(K0598) LH2 Depletion Sensor No. 2 Wet
(K0599) LH2 Depletion Sensor No. 3 Wet
(K0676) LH2 Depletion Sensor No. 4 Wet

The measurement data indicated the following: sensor No. 3 first showed a wet indication 63.37 sec after the start of loading; sensor No. 2 first showed a wet indication 106.574 sec later; sensor No. 1 showed a wet indication 6.767 sec after No. 2 did; sensor No. 1 cycled abnormally from wet to dry from submergence to 92 percent of LH2 loading; in the terminal countdown, there was no indication of cycling; sensors No. 2, 3 and 4 after being submerged, performed as expected.

(K0601) LOX Depletion Sensor No. 1 Wet
(K0602) LOX Depletion Sensor No. 2 Wet
(K0603) LOX Depletion Sensor No. 3 Wet
(K0675) LOX Depletion Sensor No. 4 Wet

The measurements verified that the LOX depletion sensors performed as expected.

*Hardwire measurements are in parenthesis.

12.2 APS Electrical Control System

The APS simulator No. 188B was activated for verification of the APS No. 1 and No. 2 engines control function.

Exhibits of the engine feed valves verify that the electrical control system performed within prescribed limitations.

The monitored results are shown in the following table:

<u>Measurement No.</u>	<u>Function</u>	<u>Specified Minimum Value</u>	<u>Actual Value</u>
K0132	APS Engine 1-1/1-3 Feed Valves Open	3.2 vdc	4.02
K0133	APS Engine 1-2 Feed Valves Open	3.2 vdc	4.09
K0134	APS Engine 2-1/2-3 Feed Valves Open	3.2 vdc	3.98
K0135	APS Engine 2-2 Feed Valves Open	3.2 vdc	4.01

The specified minimum value of 3.2 vdc indicates that all of the feed valves were open.

12.3 Electrical Power System

The electrical power system performed satisfactorily throughout the acceptance firing. The voltage, current, and simulator temperature profiles are shown in figures 12-1 through 12-3.

12.3.1 Static Inverter-Converter

The static inverter-converter operated within its required limits during the firing. Its actual values are shown in the following table:

<u>Characteristics</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Acceptable Limits</u>
Voltage (vrms)	114.1	114.1	115.0 \pm 3.45
Voltage (vdc)	5.1	5.1	5.0 \pm 0.5
Voltage (vdc)	21.81	21.79	21.0 \pm 1.5 -1.0
Frequency (cps)	401.3	401.1	400.0 \pm 6.0

12.3.2 5-Volt Excitation Modules

The performance of the forward No. 1 and No. 2, and aft 5-volt excitation modules was satisfactory during the acceptance firing. The actual values are shown in the following table:

<u>Characteristics</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Acceptance Limits</u>
Aft voltage (vdc)	5.02	5.01	5.0 \pm 0.05
Forward 1 voltage (vdc)	4.98	4.98	5.0 \pm 0.05
Forward 2 voltage (vdc)	4.98	4.97	5.0 \pm 0.05

12.3.3 Chilldown Inverters

The chilldown inverters performed satisfactorily during the acceptance firing.

During the operation of the chilldown inverters, some data exhibited approximately 2 percent noise; since this occurred prior to engine start, it did not degrade any of the engine performance data.

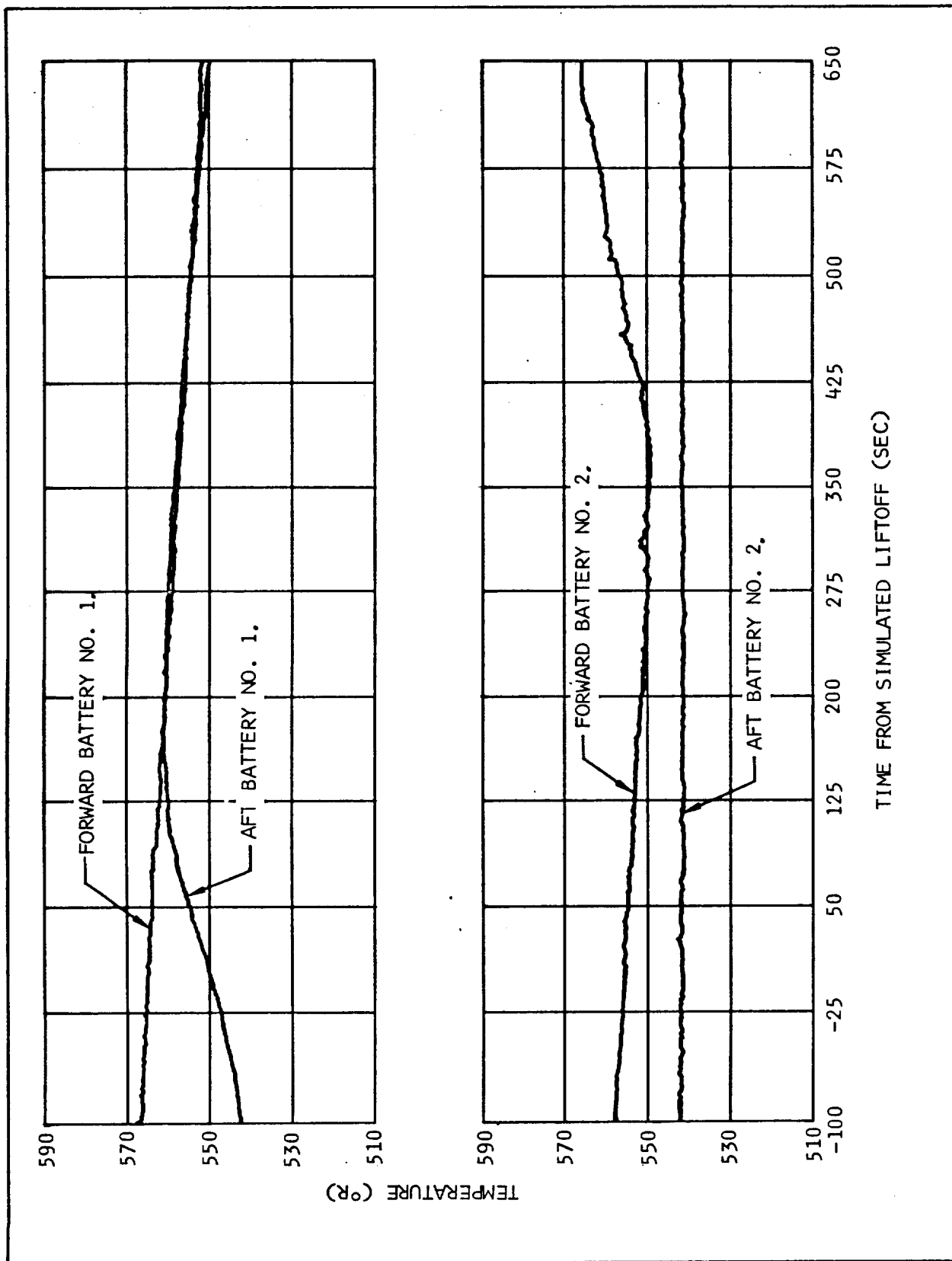


Figure 12-1. Battery Temperatures

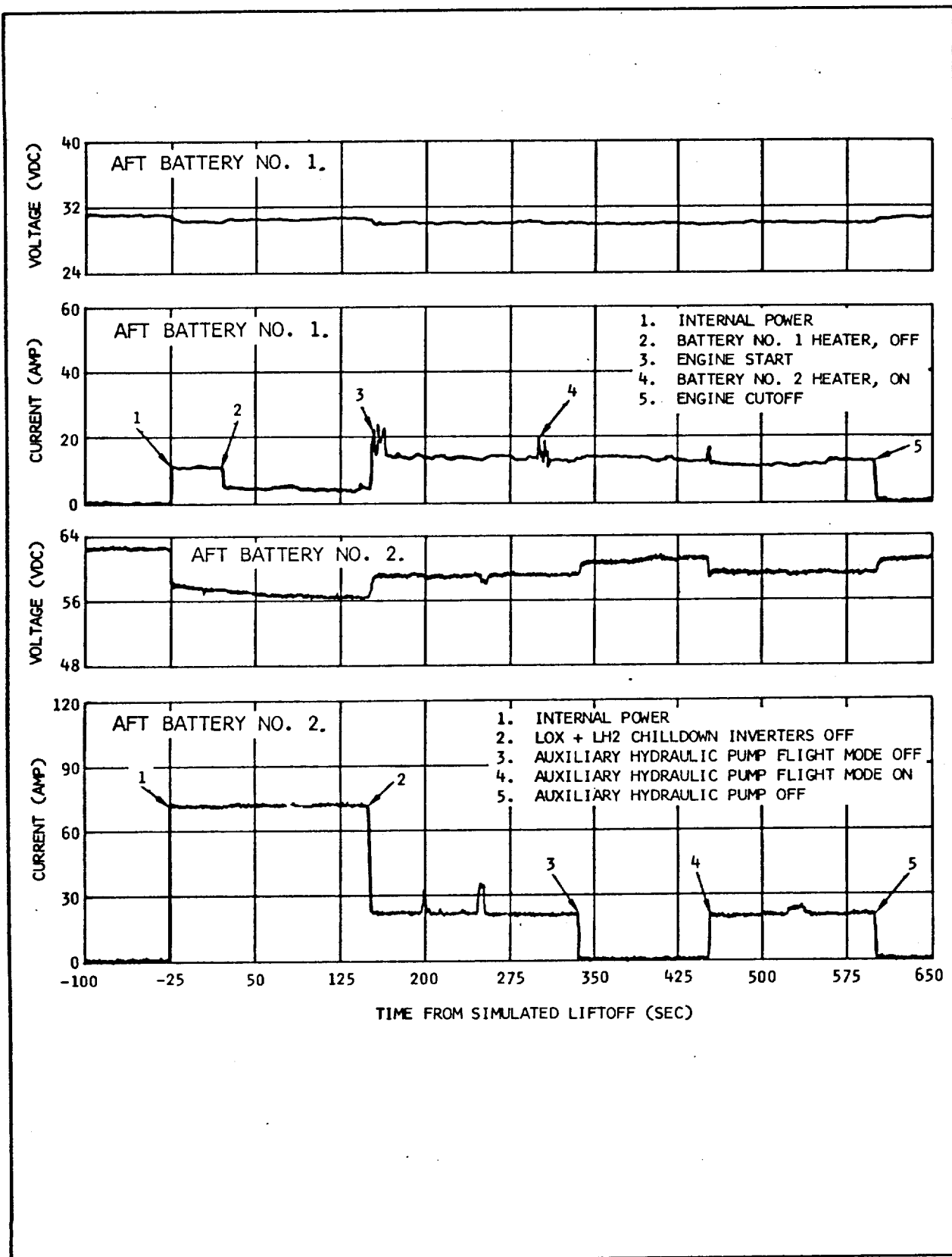


Figure 12-2. Aft Battery Voltage and Current Profiles

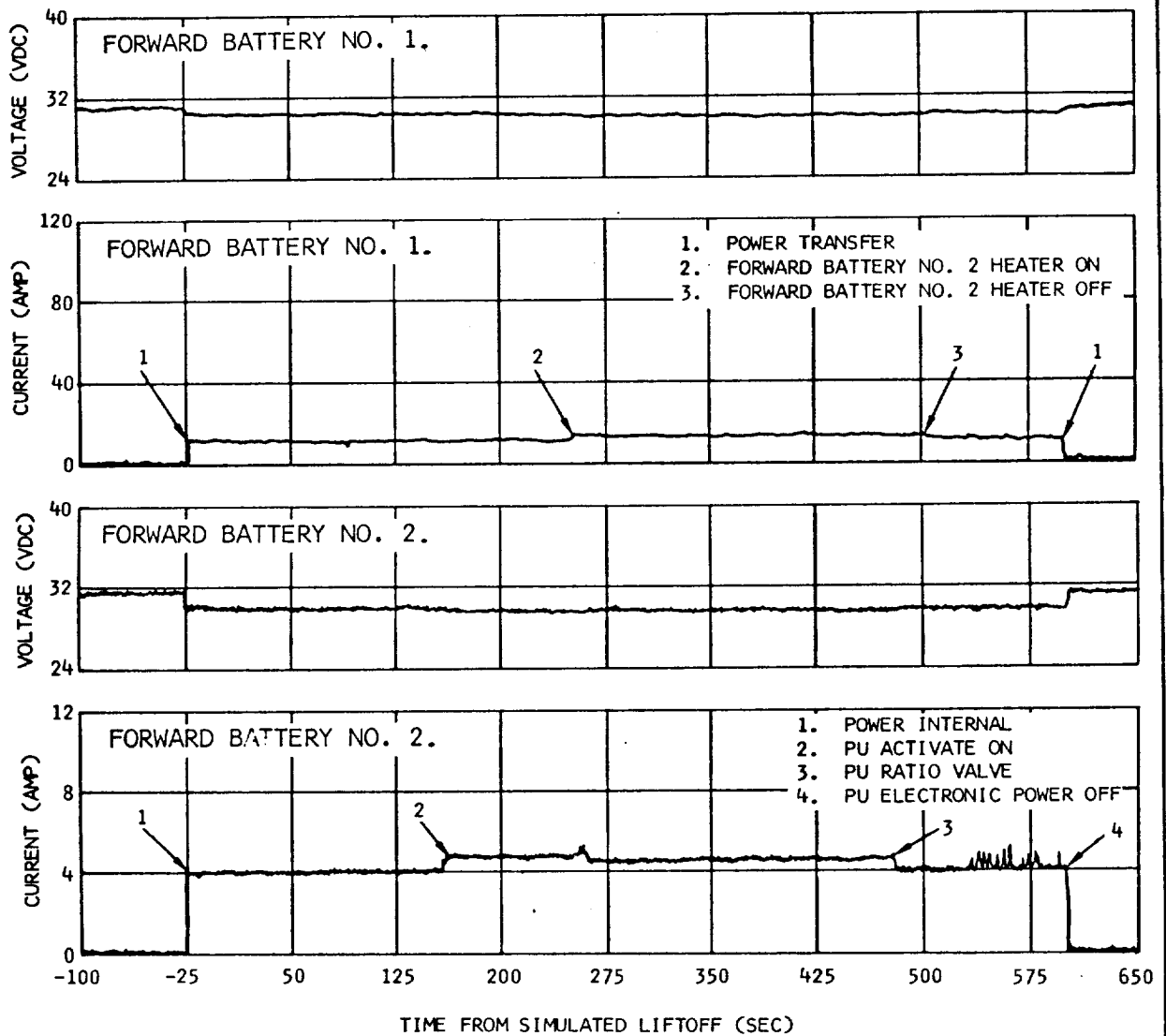


Figure 12-3. Forward Battery Voltage and Current Profiles

SECTION 13

HYDRAULIC SYSTEM

13. HYDRAULIC SYSTEM

13.1 Hydraulic System Operation

The hydraulic system test program was completed during countdown 614074. System running time for this test, from auxiliary pump ON prior to simulated liftoff to auxiliary pump OFF following cutoff, was 1,709.7 sec. The gimbal program was initiated after the engine start sideloads subsided and the support links dropped. The auxiliary pump was turned off for a period during the firing to verify engine-driven pump operation. These plan objectives were satisfied.

Significant event times are presented in the following table:

<u>Event</u>	<u>Time (sec)</u>
Auxiliary Pump ON	To -609.2
Simulated Liftoff	To + 0
Engine-driven Pump START	To + 151.6
Support Links DROPPED	To + 190.0 (pitch) To + 190.6 (yaw)
Gimbal Program START	To + 196.7
Gimbal Program STOP	To + 252.5
Auxiliary Pump OFF	To + 336
Auxiliary Pump ON	To + 452
Engine Cutoff Engine-driven Pump STOP	To + 599.3
Auxiliary Pump OFF	To + 1100.5

13.2 System Pressure at Salient Times

The GN2 precharge, averaged from stabilized readings prior to and following the acceptance firing, was 2,330 psia at 68 deg F, which is within the 2,350 \pm 50 psig allowable and corresponds closely to the observed value of 2,340 psia during the prefire checkout.

Auxiliary pump output pressure was 3,535 psia when first energized at To -609.2 sec. This value is less than the 3,550 minimum allowable, and is substantiated by GN2 pressure, but is acceptable because the small (15 psi) value in question is well within the instrumentation error band, and more significantly, the auxiliary pump output was reading a minimum of 3,550 psia no later than To -170 sec. Simulated launch requirements were met.

The engine-driven pump output was 3,580 psia; it carried the system leakage flow requirement throughout the firing. The auxiliary pump shared some of the gimbal flow requirement as seen in the auxiliary pump motor amperage demand, but the compensator settings were sufficiently spread to preclude the auxiliary pump from assuming system leakage flow at any time the engine-driven pump was running.

GN2 pressure data duplicated system pressure data. Significant pressures are presented in the following table:

<u>Time (sec)</u>	<u>System Pressure (psia)</u>	<u>Reservoir Pressure (psia)</u>
To -609.2	3,535	162
To + 0	3,550	172
To + 151.6	3,580 (3,645 overshoot at start)	175
To + 196.7 to 252.5	3,630 max. 3,480 min.	177 max. 167 min.
To + 336 to 452	3,580	174

13.3 Reservoir Level at Salient Times

Reservoir level prior to system operation was 88.2 percent at an approximate average system temperature of 40 deg F, equivalent to 92.6 percent at 70 deg F. Minimum level during operation was 31.3 percent. A malfunction in the recording machinery at To +225 sec prevented further observation of level, but it may be said to its credit that the level was behaving quite well until that time. Fluid thermal expansion was not great enough to cause overboard venting; this was established because return pressure did not increase during or after system bleed-down following auxiliary pump OFF at To +1,100.5 sec.

13.4 Hydraulic Fluid Temperature History

<u>Time (sec)</u>	<u>Engine-driven Pump Inlet (°F)</u>	<u>Reservoir (°F)</u>	<u>Accumulator GN2 (°F)</u>
To -609.2	40	40	52/64
To + 151.6	91	73	64
To + 196.7	98	73	64
To + 252.5	102	75	64
To + 336	110	78	64
To + 452	110	82	64
To + 599.3	129	86	64
To + 1,100.5	125	109	64

13.5 Engine Side Loads

Peak loads in the support links and actuators during engine start transients are presented in the following tables:

<u>Item</u>	<u>Load (lbf)</u>
Pitch Link	+ 9,500 -16,500
Yaw Link	+24,500 -13,500
Pitch Actuator	+14,160 -1,770
Yaw Actuator	+ 1,180 -16,500

13.6 Hydraulic Fluid Flowrates

Approximations from reservoir fill and emptying rates are presented in the following table:

<u>Item</u>	<u>Flow (gpm)</u>	<u>Allowable (gpm)</u>
System internal leakage	0.71	0.4 to 0.8
Auxiliary pump maximum flowrate	1.80	1.50 min

13.7 Miscellaneous

Approximation from actuator differential pressures immediately prior to and following cutoff, using 164K net thrust; thrust offset was 0.044 in. from the stage longitudinal axis, 9-1/2 deg from fin plane III toward fin plane II.

A thermal cycle was initiated by the thermal switch at T_0 -9,212 sec; the auxiliary pump ran for 12 min, 20 sec; the thermal cycle was then terminated by the thermal switch. Initial and final values of reservoir oil temperature were 23 deg F and 51 deg F; engine-driven pump inlet temperatures were 32 deg F and 69 deg F.

SECTION 14

FLIGHT CONTROL SYSTEM

14. FLIGHT CONTROL SYSTEM

The dynamic response of the hydraulic-servo thrust vector control system was measured while the J-2 engine was gimballed during the acceptance firing of the S-IVB-207 stage. The performance of the pitch and yaw hydraulic servo control systems was found to be acceptable.

14.1 Actuator Dynamics

The actuator frequency response of the pitch and yaw hydraulic servo system for a $\pm 1/2$ deg sinusoidal signal between 0.6 and 9 cps, and for a $\pm 1/4$ deg sinusoidal signal between 0.6 and 2 cps are plotted in figures 14-1 and 14-2. The acceptable limits are also presented and as noted, the phase and gain plot within these limits.

14.2 Engine Slew Rates

A nominal two deg step command was applied to the pitch and yaw actuators from which the engine slew rates were determined. The minimum acceptable engine slew rate is 8 deg per sec, which corresponds to an actuator piston travel rate of 1.66 ips. A nominal slew rate for a two deg step without the effects of gimbal friction is 13.6 deg per sec. The measured values were found to be acceptable and are presented in the following table:

<u>Actuator</u>	<u>Condition</u>	<u>Engine Travel (deg)</u>	<u>Actuator Rate (deg/sec)</u>
Pitch	Retract	0.0 to +2.0	11.0
	Extend	+2.0 to 0.0	11.9
	Extend	0.0 to -2.0	11.6
	Retract	-2.0 to 0.0	10.6
Yaw	Extend	0.0 to +2.0	9.9
	Retract	+2.0 to 0.0	9.7
	Retract	0.0 to -2.0	10.4
	Extend	-2.0 to 0.0	10.0

The minimum engine slew rate is 9.7 deg per sec which corresponds to an actuator piston rate of 2.01 ips when using a conversion of 4.83 deg of

engine travel per in. of actuator movement; thus, in all cases, the actuator exceeded the minimum acceptable rate of 1.66 ips, or 8 deg per sec of engine travel.

14.3 Differential Pressure Feedback Network

The differential pressure feedback network in the pitch and yaw hydraulic servo valves was operating properly since adequate system damping was demonstrated by observing the actuator differential pressure measurements during the two deg step response tests. The differential pressures decreased in amplitude as a function of time without sustained ringing (figure 14-3).

14.4 Cross-Axis Coupling

Cross-axis coupling is obtained from actuator piston differential pressure data. The cross-axis coupling from the yaw to the pitch plane and from the pitch to the yaw plane did not exceed 12 percent.

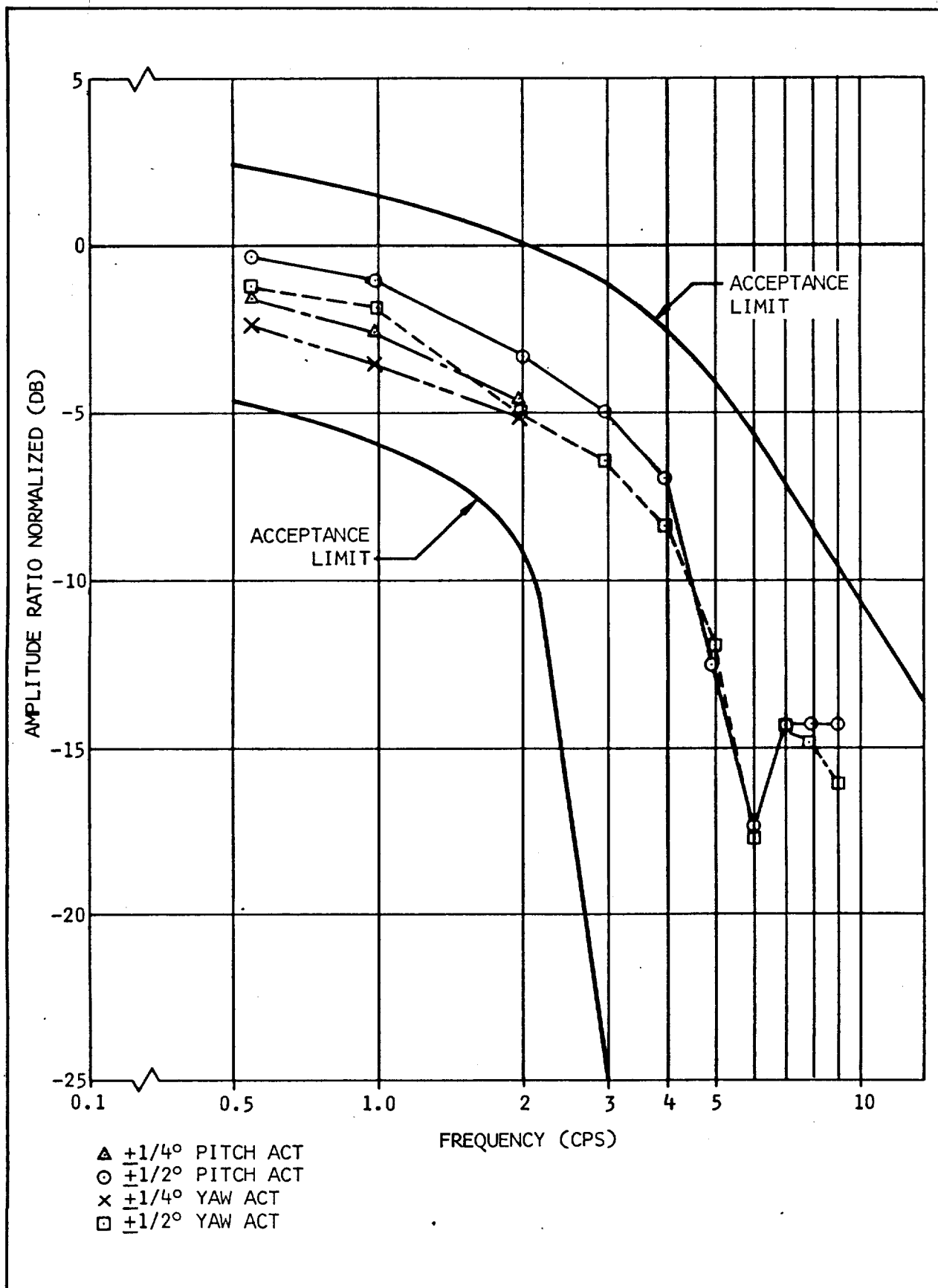


Figure 14-1. Actuator Response (Gain)

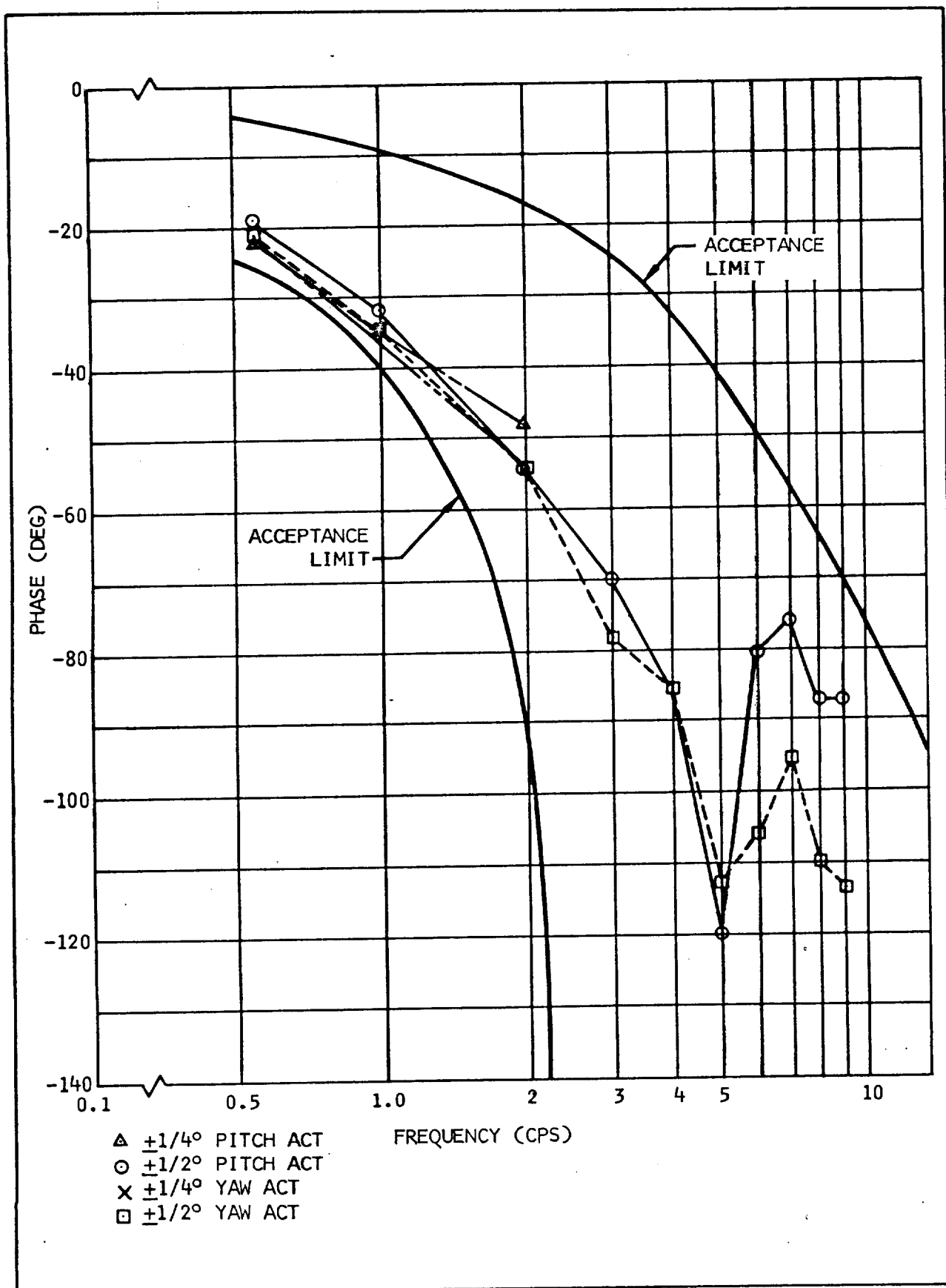


Figure 14-2. Actuator Response (Phase Lag)

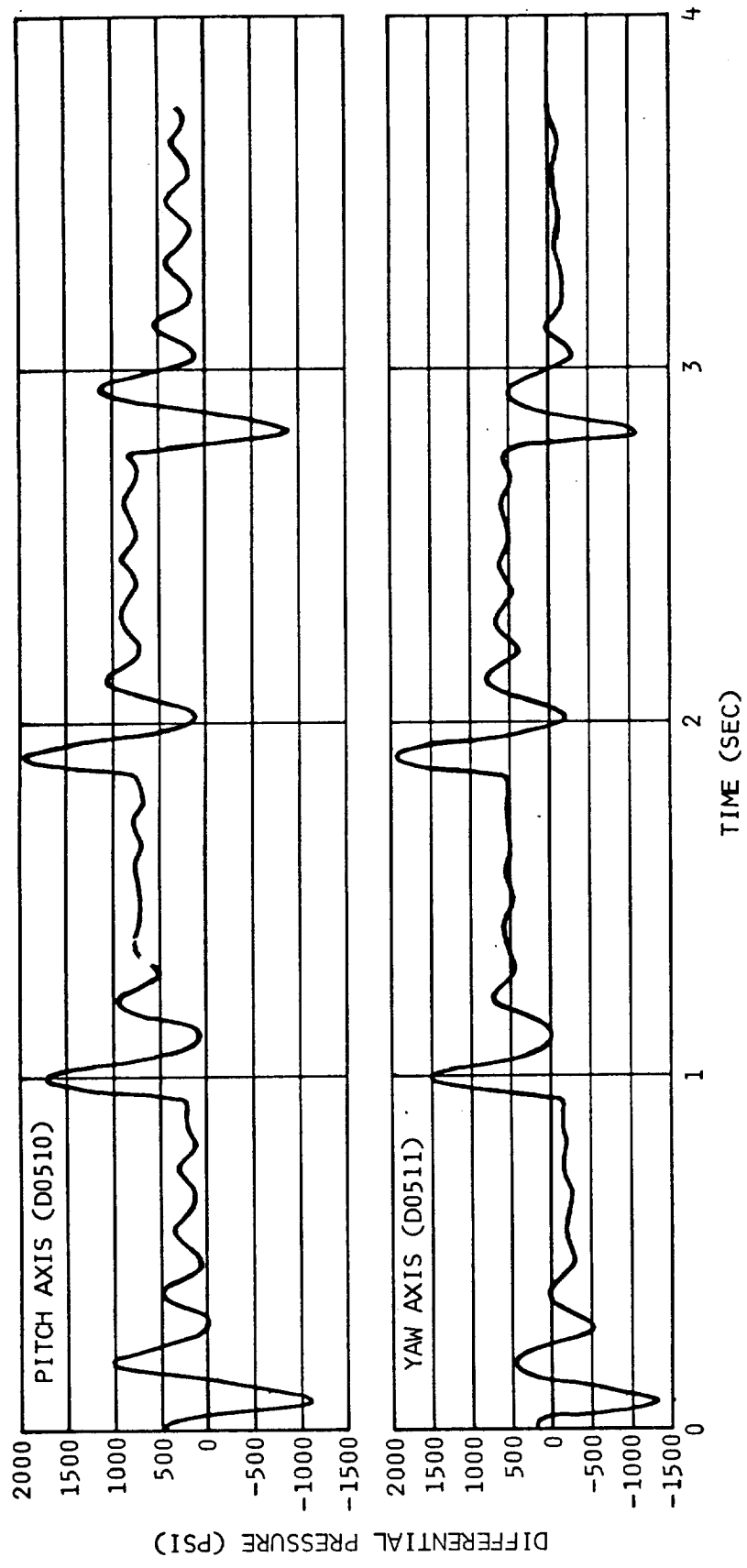


Figure 14-3. Actuator Differential Pressure (± 2 deg Transient Response)

SECTION 15

STRUCTURAL SYSTEM

15. STRUCTURAL SYSTEMS

Structural integrity of the S-IVB-207 stage was maintained for the vibration, temperature, and thrust load conditions of the acceptance firing. No structural irregularities were detected during the post firing inspection. There was no apparent debonding of the standoff supports or the aft skirt purge manifold fabric seal, as occurred during previous acceptance firings.

15.1 Common Bulkhead

Visual, growler, and dye check inspections of the common bulkhead, after acceptance firings, have been discontinued in view of the experience and confidence gained from previous acceptance firings; however, common bulkhead pressure decay checks and gas sample surveys are being continued as a means of verifying bulkhead leak-tight integrity. These checks and surveys indicated the bulkhead is sound and leak tight. The bulkhead internal pressure during the firing was less than 1 psia. The results of the pressure checks and gas surveys are presented in Douglas Report No. SM-37543, S-IVB-207 Stage Acceptance Firing (15 Day) Report, dated November 1966.

15.2 LH2 Tank Interior

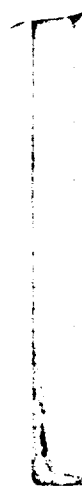
A postfire visual inspection of the LH2 tank interior was made from the manhole. The inspection revealed no discrepancies.

15.3 Exterior Structure

A visual exterior inspection of the stage thrust structure, LOX tank aft dome, aft skirt, LH2 tank cylindrical section, LH2 tank forward dome, and forward skirt revealed no structural damage after the full duration firing. The inspection revealed no debonding of standoff supports, whereas in previous acceptance firings partial debonding has been a recurring problem. This completely successful bonding appears to be the result of improved skills and inspections combined with the use of Silane primer to prepare the metal surfaces.

15.4 Aft Skirt Purge Manifold

After the acceptance firing, a visual inspection of the fabric seal of the redesigned aft skirt purge manifold revealed no debonding of the seal. A postfiring pressure leak test of the manifold indicated the fabric seal and bonding were sound. This was a completely satisfactory checkout of the redesigned purge manifold which supersedes and replaces the original purge manifold configuration.



SECTION 16

THERMOCONDITIONING AND PURGE SYSTEMS

16. Thermoconditioning and Purge Systems

16.1 Aft Skirt Thermoconditioning and Purge System

The aft skirt GN2 purge was initiated prior to LOX loading and maintained throughout the acceptance firing until completion of final tank purges. The system performed satisfactorily throughout the firing.

16.1.1 Aft Skirt GN2 Flowrate

The GN2 flowrate was maintained between 3,400 and 3,500 scfm throughout the acceptance firing.

16.1.2 Aft Skirt GN2 Temperature

The aft skirt umbilical inlet temperature was approximately 107 deg F throughout the firing. GN2 temperature at the APS module thermoconditioning system outlet sensors (C0663) was constant at 91 deg F.

16.1.3 Aft Skirt Umbilical Inlet Pressure

The umbilical inlet pressure (D0767) was constant at approximately 14.0 in. H₂O throughout the firing.

16.1.4 Non-Flight Hardware

a. APS Modules:

The flight modules were replaced with two Model DSV-4B-188B APS simulators at APS positions 1 and 2. These replacements functionally represent the flight module thermoconditioning system.

b. Aft Interstage:

The Model DSV-4B-540 Dummy Interstage was used to support the stage on the test stand. Use of the dummy interstage lowers the aft skirt purge system internal pressures very slightly, but does not materially affect the overall system purge capabilities.

16.2 Forward Skirt Environmental Control and Thermoconditioning System

The forward skirt GN2 purge was initiated prior to LOX loading and maintained throughout the acceptance firing until completion of final tank purges. The Model DSV-4B-359 thermoconditioning system servicer temperature controller malfunctioned which caused the thermoconditioning fluid temperature to rise. The resultant cold plate fluid temperature was acceptable for the test although not to design requirements.

16.2.1 Forward Skirt GN2 Flowrate

The GN2 flowrate was maintained at design conditions of 500-600 scfm throughout the firing.

16.2.2 Forward Skirt GN2 Temperature

The forward skirt GN2 internal temperature (C0768) remained between 40 and 46 deg F throughout the firing.

16.2.3 Forward Skirt Internal Pressure

The forward skirt internal pressure remained well below the relief valve setting of 2.0 in. H₂O.

16.2.4 Forward Skirt Thermoconditioning System Temperature

Due to the DSV-4B-359 servicer temperature controller malfunction, the thermoconditioning system fluid inlet temperature (C0753) ranged from 70 deg F at initiation of the test to a minimum of 62 deg F when cryogenics were on board.

The design temperature range for the system inlet is 57 \pm 7 deg F.

16.2.5 Non-Flight Hardware

Model DSV-4B-359 Thermoconditioning System Servicer: The servicer supplies thermally conditioned fluid to the forward skirt cold plates during all field station operations requiring power to the forward skirt electronic equipment. When staged, the cold plates will receive fluid from the NASA I.U. thermoconditioning system.

SECTION 17

RELIABILITY AND HUMAN ENGINEERING

17. RELIABILITY AND HUMAN ENGINEERING

17.1 Reliability Engineering

All functional failures of Flight Critical Items (FCI) and Ground Support Equipment/Special Attention Items (GSE/SAI) were investigated by Reliability Engineering. Significant malfunctions of Flight Critical Items documented are noted in table 17-1.

17.2 Human Engineering

A Human Engineering evaluation of the S-IVB-207 stage acceptance firing was performed. No significant man-machine problems were identified.

TABLE 17-1 (Sheet 1 of 2)
FLIGHT CRITICAL COMPONENTS MALFUNCTIONS

P/N AND S/N	PART	TROUBLE	CAUSE	ACTION TAKEN
1A48240-505 S/N 0103	Valve, Fill and Drain	Valve failed during production acceptance test at Santa Monica facility. Valve was leaking 400 scim at -400 degrees F; at -350 degrees F leakage was 195 scim. Allowable leakage is 164 scim. No apparent cause of failure was ascertained. Engineering accepted the part for static firing only; however, the FARR tag (A205445) was inadvertently closed out and the valve was shipped to A45 without any special identification. Upon disclosure of said condition FARR A214901 was generated at A45 to cover the leakage problem.	To be determined	Valve will be returned to A-MRCG for further evaluation as soon as a replacement becomes available at A45.
1A49965-515 S/N 0403	Valve, Shutoff, Chill System	Valve exhibited erratic talkback during the critical components test of Task 44, CD 614074. Valve failed to provide open talkback and after several cycles, the closed talkback was also lost; however, during the firing, the talkback indications were normal.	Undetermined.	Valve replaced with a new configuration valve (-519) created by E.O. 1A59098 Chg. "BU". New configuration provides redesigned valve poppets and guides and is expected to decrease the internal leakage of valve. Removed valve was sent to vendor for rework to -519 configuration. Micro-switches will be removed and evaluated for possible failure analysis.

TABLE 17-1 (Sheet 2 of 2)
FLIGHT CRITICAL COMPONENTS MALFUNCTIONS

P/N AND S/N	PART	TROUBLE	CAUSE	ACTION TAKEN
1A49965-517 S/N 0203	Valve, Shutoff, Chilldown System	Valve exhibited no open talk-back during the critical cycling portion of Task 44, CD 614074. Data review revealed that the valve functioned properly, thus isolating the problem in the talk-back microswitches. Proper talkback signals were received during terminal count, Task 45.	Undetermined	Replaced with a new configuration valve (-521) created by E.O. 1A49965 Chg. "Y". Replacement was authorized per E.O. 1A59098 Chg. "BU". New configuration provides redesigned valve poppets and guides and is expected to decrease the internal leakage of the valve. Valve will be removed and sent to vendor for rework to -521 configuration. Microswitches will be removed and evaluated for possible failure analysis.
1A49988-1 S/N 0019	Valve, Directional Control, Fuel Vent	Valve failed during propulsion system leak checks. Valve was leaking 240 scim in the flight mode. Allowable leakage is zero scim.	To be determined	Faulty valve was replaced with a like valve (S/N 0012) and faulty valve was returned to the vendor for investigation and rework.
1A59358-527 S/N 023	Electronics Assembly, Propellant Utilization	Failed during PU manual calibration checkout. Coarse mass potentiometer R2 could not be adjusted to repeat a null point within ± 0.5 mv of the previous setting.	To be determined	Unit was shipped to A-MRCC for replacement of the defective part. Assembly was returned from A-MRCC to A45 and again found to be defective. Assembly was shipped again to A-MRCC for further evaluation and repair. Assembly was replaced with a like unit (S/N 00002) taken from S-IVB-206.

AP 1

ENGINE PERFORMANCE
PROGRAM (PA49)

1. ENGINE PERFORMANCE PROGRAM (PA49)

This appendix contains the digital printout of computer program PA49. which is a compilation of computer programs AA89, G105, and F823.

These computer programs are the methods employed in the propulsion system performance reconstruction of the S-IVB-207 stage acceptance firing. The performance analysis and associated plots are presented in section 6.

Printout symbols are presented in table AP 1-1 and the digital printout is contained in table AP 1-2.

TABLE AP 1-1
PROGRAM PA49 PRINTOUT SYMBOLS

FSUB1	Stage thrust from AA89 (lbf)	EMR 3	Engine mixture from F823
WDOTT1	Total flowrate from AA89 (lbm/sec)	ISP 3	Specific impulse from F823 (sec)
WDOTO1	LOX flowrate from AA89 (lbm/sec)	MSUB03	LOX mass onboard from F823 (lbm)
WDOTF1	LH2 flowrate from AA89 (lbm/sec)	MSUBF3	LH2 mass onboard from F823 (lbm)
EMR 1	Engine mixture ratio from AA89	FSUB4	Predicted stage thrust (lbf)
ISP 1	Specific impulse from AA89 (sec)	WDOTT4	Predicted total flowrate (lbm/sec)
MSUB01	LOX mass onboard from AA89 (lbm)	WDOTO4	Predicted LOX flowrate (lbm/sec)
MSUBF1	LH2 mass onboard from AA89 (lbm)	WDOTF4	Predicted LH2 flowrate (lbm/sec)
FSUB2	Stage thrust from G105 (lbf)	EMR 4	Predicted engine mixture ratio
WDOTT2	Total flowrate from G105 (lbm/sec)	ISP 4	Predicted specific impulse (sec)
WDOTO2	LOX flowrate from G105 (lbm/sec)	MSUB04	Predicted LOX mass onboard (lbm)
WDOTF2	LH2 flowrate from G105 (lbm/sec)	MSUBF4	Predicted LH2 mass onboard (lbm)
EMR 2	Engine mixture ratio from G105	THRUST	Composite stage thrust (lbf)
ISP 2	Specific impulse from G105 (sec)	T FLOW	Composite total flowrate (lbm/sec)
MSUB02	LOX mass onboard from G105	O FLOW	Composite LOX flowrate (lbm/sec)
MSUBF2	LH2 mass onboard from G105 (lbm)	F FLOW	Composite LH2 flowrate (lbm/sec)
FSUB 3	Stage thrust from F823 (lbf)	*EMR*	Composite engine mixture ratio
WDOTT3	Total flowrate from F823 (lbm/sec)	*ISP*	Composite specific impulse (sec)
WDOTO3	LOX flowrate from F823 (lbm/sec)	O MASS	Composite LOX mass onboard (lbm)
WDOTF3	LH2 flowrate from F823 (lbm/sec)	F MASS	Composite LH2 mass onboard (lbm)

TABLE AP 1-2 (Sheet 1 of 5)
ENGINE PERFORMANCE PROGRAM (PA49)

TIME	FSUR 2	FSUR 3	FSUR 4	THURST	8.000	8.000	8.000	8.000
FSUR 1	FSUR 2	FSUR 3	FSUR 4	T FLOW	224538.908	220647.771	221187.875	201962.283
W00T11	W00T12	W00T13	W00T14	F FLOW	530.488	514.662	519.502	473.214
W00T01	W00T02	W00T03	W00T04	F FLOW	449.168	432.966	439.032	394.715
W00T01	W00T02	W00T03	W00T04	F FLOW	81.520	80.469	80.469	78.592
ENR 1	ENR 2	ENR 3	ENR 4	0.000	5.510	5.300	5.456	5.422
ISP 1	ISP 2	ISP 3	ISP 4	0.000	422.770	428.802	429.766	426.788
MSUR01	MSUR02	MSUR03	MSUR04	0.000	199339.186	190550.456	190511.119	191056.756
MSUR01	MSUR02	MSUR03	MSUR04	F MASS	36691.551	36709.100	36751.559	36921.309
0.000	0.000	0.000	0.000	0.000	9.000	9.000	9.000	9.000
0.000	1084.439	1351.957	0.000	812.137	225627.268	222023.442	222300.887	223796.898
0.000	0.140	1.897	0.000	0.679	532.313	518.896	522.566	528.251
0.000	0.140	0.899	0.000	0.364	451.081	437.052	441.368	447.208
0.000	0.000	0.000	0.000	0.336	81.253	81.846	81.205	81.043
0.000	0.000	0.000	0.000	0.295	5.551	5.340	5.435	5.418
0.000	7728.183	712.569	0.000	281.546	423.461	427.878	425.404	423.634
192655.000	192656.000	192656.000	193273.000	192656.000	189888.723	190114.783	190069.361	190024.285
37203.000	37203.000	37203.000	37427.000	37203.000	36609.853	36626.930	36670.608	36941.030
1.000	1.000	1.000	1.000	1.000	10.000	10.000	10.000	10.000
19.277	372.444	447.281	0.000	273.747	226411.672	223962.609	224387.373	226713.779
0.000	25.942	4.224	19.406	14.481	533.717	522.590	527.531	536.180
0.000	7.270	1.177	0.000	2.816	452.735	440.428	446.391	453.049
19.277	18.577	3.047	19.406	13.665	80.983	82.152	81.140	81.131
0.000	0.389	0.386	0.000	0.290	5.591	5.361	5.501	5.584
0.000	14.357	105.902	0.000	47.086	424.966	428.571	426.354	424.415
192655.598	192655.082	192655.893	193272.652	192655.180	189436.496	189675.789	189625.107	190196.756
37203.736	37146.478	37203.579	37424.194	37149.730	36528.376	36544.712	36549.042	36759.458
2.000	2.000	2.000	2.000	2.000	15.000	15.000	15.000	15.000
42510.931	55792.284	56941.465	91452.702	44255.793	226659.980	224958.896	225142.939	226672.727
202.299	127.174	99.325	199.947	147.933	533.408	529.341	529.414	533.884
148.578	80.564	79.374	146.777	99.919	452.735	440.428	446.391	453.049
53.721	45.670	28.952	53.178	43.114	81.017	81.017	81.017	81.125
2.765	1.725	2.431	2.760	2.307	5.584	5.462	5.529	5.581
457.625	434.774	573.277	457.345	449.492	424.928	424.979	425.265	424.441
192597.221	192675.454	192633.746	193215.157	192617.152	187171.406	187450.074	187382.813	187913.101
37155.911	37155.447	37170.525	37379.156	37167.427	36121.551	36124.041	36181.259	36351.733
3.000	3.000	3.000	3.000	3.000	20.000	20.000	20.000	20.000
193264.754	143104.762	143897.457	191577.893	173421.457	226843.438	225508.820	225935.508	226438.141
431.764	354.720	374.423	428.120	388.304	533.475	530.000	530.000	533.475
353.578	292.680	308.393	350.476	314.217	452.522	449.004	450.841	452.341
78.187	46.549	46.030	77.244	79.089	80.952	81.002	80.709	81.002
4.522	4.431	4.471	4.442	4.441	5.590	5.543	5.692	5.579
447.815	454.685	437.735	447.735	445.478	424.827	425.492	426.251	424.441
192331.377	192425.012	192435.205	192951.478	192397.104	184907.301	185203.137	185119.914	185644.649
37091.494	37099.451	37135.610	37314.405	37194.784	35714.452	35724.729	35777.084	35944.113
3.455	3.455	3.455	3.455	3.455	25.000	25.000	25.000	25.000
193470.622	181157.422	182545.344	191719.990	185794.174	226826.018	225306.156	225417.143	226342.707
445.598	414.261	421.040	447.791	427.300	533.510	530.663	530.663	533.510
367.364	340.584	350.982	364.412	357.957	452.576	450.035	449.478	452.211
79.294	73.674	70.058	78.379	76.342	80.934	80.649	79.911	80.649
4.632	4.423	4.410	4.469	4.755	5.592	5.592	5.592	5.579
192164.908	192777.146	192778.516	192786.474	192247.210	182642.584	182954.135	182864.031	183385.742
37054.746	37067.242	37104.549	37278.496	37075.912	35308.183	35319.650	35377.826	35536.718
4.000	4.000	4.000	4.000	4.000	30.000	30.000	30.000	30.000
194000.980	146008.158	14734.494	192478.723	189514.450	226704.475	225714.211	225978.494	226382.625
458.019	430.819	435.917	454.758	441.484	533.791	531.383	531.383	533.791
378.846	354.717	361.270	374.775	364.711	452.442	450.663	450.771	452.375
79.173	74.802	74.667	78.130	76.874	80.944	80.741	79.676	80.741
4.785	4.609	4.840	4.895	4.745	5.594	5.594	5.594	5.581
473.505	433.844	437.436	473.299	429.287	424.716	424.767	425.923	424.415
191962.904	192748.107	192844.451	192594.129	192045.152	180716.910	180699.008	180606.123	181122.498
37011.452	37026.712	37044.693	37235.083	37034.252	34901.507	34913.120	34975.994	35129.476
5.000	5.000	5.000	5.000	5.000	35.000	35.000	35.000	35.000
195054.781	191018.452	191574.402	193611.174	192549.344	226805.113	226350.455	226501.973	226421.404
459.230	419.459	444.892	454.121	448.687	534.773	532.161	531.865	533.534
380.340	361.556	369.837	377.909	373.501	451.066	451.749	452.029	452.281
78.809	74.263	77.055	78.713	78.069	81.004	80.613	79.834	80.995
4.821	4.620	4.870	4.832	4.747	5.593	5.604	5.662	5.587
424.743	416.271	428.682	424.474	429.232	424.670	425.182	425.864	424.340
191582.785	191720.461	191717.905	192298.637	191674.713	178109.928	178439.451	178364.309	178454.437
36932.731	36948.141	36989.160	37147.299	36954.337	34494.894	34507.989	34576.727	34722.370
6.000	6.000	6.000	6.000	6.000	40.000	40.000	40.000	40.000
195761.278	192402.352	193487.414	194764.287	194014.947	226794.469	225778.021	225819.154	226460.184
459.505	445.470	451.150	457.437	452.042	534.172	531.944	530.391	533.670
390.913	367.731	374.720	376.462	374.271	453.172	451.281	450.275	452.703
79.593	74.395	76.430	77.095	77.871	80.999	80.664	80.115	80.997
4.847	4.679	4.903	4.859	4.810	5.595	5.595	5.620	5.591
426.026	432.806	428.874	425.441	429.236	424.572	424.439	425.760	424.345
191271.563	191364.221	191344.466	191929.639	191301.422	175841.766	176177.438	176080.873	176593.433
36853.408	36869.106	36910.966	37074.733	36878.050	34688.123	34702.724	34715.938	34715.938
6.170	6.170	6.170	6.170	6.170	45.000	45.000	45.000	45.000
196091.859	193031.902	193695.281	195121.175	194471.880	226882.424	226556.739	226820.377	226499.963
461.442	446.430	451.704	458.247	453.759	533.671	530.575	532.764	533.807
382.966	367.976	375.232	390.157	375.341	452.512	449.812	452.785	452.847
79.677	74.453	76.473	78.008	77.849	80.958	80.763	79.978	80.939
4.868	4.690	4.907	4.848	4.822	5.599	5.570	5.661	5.595
426.074	432.390	428.810	425.705	429.002	424.545	427.002	425.743	424.340
191136.625	191301.443	191280.458	191764.974	191239.449	173575.007	173924.285	173827.768	174327.824
36840.417	36856.002	36897.899	37065.386	36844.772	34881.336	34897.317	34972.081	34908.576
7.000	7.000	7.000	7.000	7.000	50.000	50.000	50.000	50.000
22215.861	215557.690	215799.113	198221.672	217769.893	226882.840	226175.672	226533.789	226238.448
526.304	496.579	506.466	465.044	499.783	533.784	531.342	531.865	533.170
446.893	416.947	425.950	396.761	429.107	452.777	450.374	452.275	452.297
81.811	80.533	80.514	78.286	80.587	81.007	80.649	79.599	80.873
5.449	5.236	5.290	4.961	5.325	5.562	5.562	5.683	5.593
421.839	434.085	429.913	424.243	427.278	424.484	425.669	425.974	424.327
190787.311	190978.732	190946.752	191446.160	190904.762	171301.293	171670.641	171567.055	172063.135
36773.399	36790.197	36832.116	37000.131	36798.638	33274.557	33291.448	33372.094	33501.983

TABLE AP 1-2 (Sheet 2 of 5)
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55.000	226430.721	227097.926	226720.162	226878.850	110.000	226425.256	226346.605	225910.236	226371.905
226617.934	533.074	533.433	533.153	533.337	226162.063	533.774	532.413	532.553	532.453
452.984	451.525	453.069	452.378	452.524	452.661	450.189	451.091	451.929	451.919
80.960	81.078	80.531	80.364	80.864	81.113	80.984	81.319	80.623	81.139
5.593	5.569	5.518	5.595	5.600	5.581	5.559	5.567	5.605	5.562
426.189	426.078	425.719	426.197	425.396	426.061	426.774	425.138	426.203	425.151
169041.578	159411.473	169299.789	169870.177	169751.613	166126.434	166643.570	166678.986	166973.954	166615.662
32687.633	32684.957	32971.667	33095.655	32908.090	28188.685	28409.444	28532.595	28432.457	28641.657
60.000	225192.653	225115.693	226277.979	225681.336	115.000	225678.564	225860.779	225809.045	225921.930
226535.623	530.127	533.466	533.721	533.967	226232.443	530.499	530.660	532.102	531.565
452.835	449.311	448.974	452.487	450.373	452.536	449.671	450.376	451.701	450.750
81.001	80.409	80.834	80.567	80.818	81.091	81.068	80.286	80.601	80.815
5.590	5.560	5.520	5.598	5.600	5.579	5.544	5.610	5.604	5.578
426.154	426.798	426.037	426.281	425.062	426.024	425.408	425.672	426.713	425.018
166778.500	167157.820	167042.873	167536.195	16802.196	161860.014	162394.152	162774.914	162663.111	162160.359
32660.620	32678.121	32568.299	32689.400	32502.406	27981.116	28003.029	28127.443	28227.352	28037.329
65.000	225282.698	225112.563	226335.795	225698.267	120.000	226113.002	226120.578	225778.105	226787.961
226696.545	533.705	533.466	533.490	533.933	226130.104	532.233	526.145	532.722	532.114
452.904	448.807	448.932	452.666	450.114	452.082	447.017	446.194	451.645	448.432
81.101	80.721	80.531	80.750	80.818	81.151	80.674	80.263	80.587	80.683
5.584	5.550	5.501	5.575	5.569	5.571	5.544	5.599	5.606	5.585
426.191	425.160	425.468	426.255	425.100	426.074	426.737	425.714	426.210	426.841
166510.885	166910.780	166793.281	166271.775	166734.082	169596.487	160147.313	169976.574	160383.260	169906.789
32651.664	32672.119	32164.510	32781.199	32906.764	27471.676	27596.270	27723.981	27822.365	27631.309
70.000	226194.105	226559.534	226318.612	226385.385	125.000	226026.139	226452.521	225861.785	226451.916
226602.320	531.547	531.882	533.466	532.345	226077.092	530.499	526.145	532.459	532.073
452.984	450.674	452.268	452.666	451.774	450.032	446.127	447.576	451.870	447.911
81.021	81.072	80.814	80.804	80.569	81.076	80.577	78.774	80.489	80.140
5.586	5.556	5.501	5.575	5.569	5.551	5.537	5.602	5.600	5.580
426.287	425.540	425.958	426.243	425.262	423.412	425.340	426.433	426.187	425.062
162245.434	162657.590	162536.592	163076.346	162679.537	137160.707	137932.635	137770.167	138172.666	137646.166
31666.666	31665.428	31751.399	31677.060	31691.164	27166.391	27191.707	27322.852	27417.345	27275.984
75.000	227170.490	227017.236	226178.336	226901.517	130.000	226182.086	226434.727	225965.467	226189.766
226566.314	533.364	533.267	533.122	533.878	226052.634	532.630	526.145	532.145	532.469
452.912	452.061	452.465	452.153	452.506	450.167	447.017	446.194	452.095	449.274
81.110	81.093	81.702	80.750	81.125	81.125	80.652	79.617	80.490	80.674
5.586	5.550	5.501	5.575	5.569	5.549	5.534	5.606	5.610	5.583
426.264	425.827	426.029	426.253	425.007	423.406	425.973	426.036	426.163	425.139
159980.730	160364.764	160268.886	160762.051	160215.301	135088.154	135673.604	135697.098	135660.963	135619.617
31239.514	31258.062	31356.811	31471.073	31284.796	26759.072	26786.857	26920.656	27012.341	26822.194
80.000	226771.130	226291.881	226038.260	226770.730	135.000	226071.867	226072.627	225133.119	225969.959
226543.648	531.570	532.111	532.779	532.555	226071.867	532.145	526.145	532.459	532.073
452.912	450.674	452.094	452.666	451.448	450.032	446.127	447.576	451.870	447.911
81.152	81.143	81.012	80.733	81.103	81.149	80.736	80.261	80.484	80.715
5.580	5.551	5.508	5.575	5.566	5.551	5.537	5.602	5.611	5.586
426.262	425.870	426.274	426.262	425.006	423.365	425.187	426.187	426.151	425.139
157714.238	158141.120	158007.311	158479.289	157954.289	132816.494	133430.986	133252.172	133598.281	133172.551
30832.238	30857.780	30955.602	31065.243	30878.496	26351.624	26381.705	26516.990	26607.341	26416.774
85.000	226691.863	226857.500	225977.342	225970.012	140.000	226066.488	226471.814	226088.184	225807.883
226160.678	530.407	530.462	532.462	531.493	225066.488	532.784	527.457	532.583	532.073
452.912	449.527	449.363	451.933	450.806	450.537	447.017	446.194	452.095	449.274
81.081	80.880	80.708	80.708	80.806	81.129	80.737	80.014	80.565	80.627
5.581	5.558	5.507	5.575	5.569	5.553	5.537	5.592	5.611	5.581
426.267	425.807	426.275	426.258	425.143	423.323	425.187	426.187	426.155	425.139
155646.586	155890.954	155751.621	156217.871	155697.055	130579.587	131100.270	131011.227	131306.029	130927.027
30625.116	30643.954	30649.669	30659.670	30672.860	25944.737	25976.617	26115.001	26202.414	26011.943
90.000	226622.114	226865.464	226963.404	226965.472	145.000	226064.289	226208.185	226386.535	225925.807
226162.114	530.456	531.008	532.837	531.872	226064.289	532.784	527.457	532.457	532.073
452.912	449.527	449.363	451.933	450.832	450.537	447.017	446.194	452.095	449.274
81.024	81.001	80.849	80.839	80.839	81.106	80.354	79.710	80.467	80.390
5.584	5.550	5.501	5.575	5.569	5.552	5.534	5.609	5.610	5.586
426.144	425.881	426.257	426.270	425.120	423.317	425.187	426.187	426.155	425.139
151184.189	151641.668	151369.146	151955.972	151641.668	128125.259	128955.757	128773.921	129074.488	128664.910
30017.884	30037.130	30145.185	30244.066	30066.813	25536.499	25571.907	25714.772	25747.580	25607.728
95.000	226277.779	226816.246	226096.873	226113.805	150.000	226083.654	226249.918	225753.730	226179.766
226189.105	531.524	530.952	533.033	532.127	226083.654	532.784	527.457	532.231	532.073
452.912	450.674	451.095	452.342	451.453	450.103	446.061	445.506	451.756	448.910
81.057	81.107	80.857	80.890	80.674	80.896	80.368	79.137	80.528	80.112
5.582	5.558	5.509	5.576	5.566	5.564	5.554	5.618	5.609	5.579
426.119	426.581	426.833	426.293	425.844	423.175	423.816	426.295	426.165	426.429
150920.598	151109.918	151242.742	151692.916	151184.719	126021.371	126722.083	126537.854	126813.931	126443.768
29610.730	29630.564	29742.142	29868.517	29661.146	25129.020	25167.303	25315.460	25392.838	25203.927
100.000	226029.944	226073.574	226115.742	226166.207	155.000	226082.848	226081.746	226081.654	226081.654
226189.105	531.781	531.483	533.037	531.812	226082.848	532.784	527.457	532.056	532.290
452.912	449.661	449.597	452.346	451.629	450.117	446.061	445.508	451.546	447.963
81.152	80.712	80.885	80.673	80.803	80.885	80.266	79.871	80.509	80.327
5.578	5.548	5.501	5.575	5.564	5.568	5.556	5.606	5.609	5.577
426.124	425.816	426.364	426.187	425.435	423.118	426.775	425.881	426.169	425.259
146665.750	146145.420	146891.135	146979.646	146930.764	123180.322	124488.714	124355.218	124554.061	124204.084
29703.344	29223.905	29741.014	29643.039	29258.089	26721.479	26762.475	26913.010	26984.190	26798.988
105.000	225726.958	226046.527	226011.430	226062.926	160.000	226022.166	226027.904	226009.578	226311.688
226435.256	533.935	530.638	532.803	531.962	226022.166	530.782	526.724	531.880	527.856
452.823	449.889	449.988	452.154	451.233	449.901	446.363	447.003	451.389	447.756
81.112	81.064	80.789	80.645	80.809	80.881	80.761	79.000	80.441	80.080
5.583	5.550	5.507	5.575	5.569	5.563	5.545	5.604	5.608	5.599
426.050	425.135	425.990	426.193	425.098	423.153	425.123	426.434	426.174	426.970
146389.721	146894.104	146735.209	147165.941	146673.010	121565.932	122756.678	122071.432	122964.664	121964.664
28795.844	28816.971	28836.872	29037.593	28848.495	26311.765	26357.585	26513.257	26583.635	26494.869

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165.000	224625.689	224875.266	225307.862	224489.757	220.000	223935.057	224262.816	225397.518	224278.174
224565.309	525.688	527.936	531.441	528.092	224636.856	526.160	526.239	531.276	527.738
530.656	445.377	446.326	451.283	447.810	530.615	445.400	446.968	450.762	447.765
449.730	80.311	79.609	80.158	80.282	81.216	80.678	79.291	80.515	80.392
80.026	5.557	5.632	5.610	5.578	5.533	5.525	5.637	5.599	5.565
5.557	427.298	425.954	423.957	425.479	423.351	425.441	426.162	426.757	424.065
423.185	120025.772	119839.496	120036.599	119726.448	94544.754	95476.827	95272.799	95191.242	95091.126
119314.209	23952.940	24111.852	24179.183	23990.269	19418.956	19490.599	19699.994	19726.883	19539.516
23905.966									
170.000	223782.358	223959.293	225358.225	224051.033	225.000	223372.963	223532.686	225428.348	223845.949
224611.412	525.456	528.430	531.557	527.077	224632.611	525.346	525.770	531.370	526.944
530.345	445.494	446.132	451.180	446.983	530.716	446.811	445.050	450.865	446.488
449.494	80.137	79.297	80.177	80.094	449.602	80.114	79.720	80.506	80.458
80.847	5.547	5.626	5.610	5.581	81.114	5.543	5.583	5.600	5.590
5.540	425.142	426.240	423.959	425.088	423.264	425.191	425.963	426.240	424.066
423.142	117796.686	117607.176	117778.322	117488.914	92300.206	93740.968	93022.283	92935.417	92857.142
117062.863	23548.378	23711.726	23774.748	23586.085	19011.327	19096.892	19298.742	19322.276	19134.987
23498.151									
175.000	224327.767	224577.879	225418.291	224507.049	230.000	223338.859	223695.385	225459.178	223825.810
224615.512	526.804	526.814	531.790	529.128	224443.496	525.056	524.700	531.444	526.683
530.767	446.468	447.596	451.450	447.967	530.290	445.259	446.542	450.967	446.504
449.788	80.339	79.217	80.199	80.178	449.259	81.032	80.517	80.497	80.179
80.974	5.557	5.650	5.630	5.487	5.544	5.521	5.643	5.602	5.569
5.554	425.426	426.295	423.956	425.104	423.247	425.360	424.330	424.271	424.979
423.190	115567.350	115372.924	115519.232	115253.817	90051.381	91029.209	90791.793	90679.076	90622.088
114812.169	23143.758	23313.455	23370.201	23182.400	18603.907	18690.878	18899.256	18917.715	18731.340
23090.189									
180.000	224729.473	224744.566	225519.157	224700.617	235.000	223880.850	224041.158	225490.006	224127.514
224607.412	528.368	528.007	531.943	529.063	224460.545	525.297	526.018	531.558	527.200
530.813	447.810	447.759	451.721	449.494	530.246	446.855	446.207	451.772	446.754
449.889	80.590	80.248	80.222	80.474	449.203	80.447	79.815	80.448	80.444
80.924	5.559	5.580	5.631	5.564	81.081	5.540	5.590	5.606	5.594
5.559	425.328	425.685	423.957	424.717	5.540	425.198	425.914	424.206	425.134
423.130	113331.146	113137.840	113298.791	113008.125	87802.948	88796.762	88554.793	88422.223	88384.166
112560.975	22738.718	22913.412	22965.540	22774.125	18196.429	18246.566	18501.665	18513.199	18328.220
22682.245									
185.000	224657.520	224764.189	225508.424	224799.223	240.000	223454.813	223509.017	225420.836	223803.018
224605.959	528.274	527.814	532.136	529.128	224445.236	525.258	525.714	531.642	527.072
531.437	447.667	447.818	451.901	449.376	530.246	446.088	446.861	451.173	446.337
449.242	80.512	80.006	80.245	80.401	449.163	80.726	80.398	80.479	80.735
81.198	5.557	5.599	5.631	5.545	81.081	5.521	5.533	5.606	5.528
5.554	425.270	425.647	423.949	424.795	423.287	425.050	425.522	424.189	424.670
423.170	110309.780	110092.909	110094.744	110765.243	85554.976	86570.924	86378.410	86164.454	86151.438
110309.780	22133.657	22508.231	22560.765	22372.014	17789.109	17481.588	18100.681	18108.724	17923.726
22274.156									
190.000	223773.605	224672.547	225547.941	224242.078	245.000	222971.345	223390.744	225515.994	223590.320
224057.082	528.907	528.907	531.981	528.054	224470.850	525.258	525.714	531.642	527.072
531.437	447.165	446.291	451.730	447.531	530.157	445.087	446.072	451.189	446.411
449.138	80.705	79.610	80.251	80.523	449.087	80.788	79.780	80.424	80.713
81.244	5.540	5.606	5.629	5.498	81.070	5.509	5.533	5.607	5.566
5.540	425.322	425.941	423.970	424.662	423.287	425.050	425.522	424.189	424.670
423.122	118056.289	118056.471	118056.475	118056.475	83107.306	84344.960	84097.918	83907.059	83916.728
118056.289	21928.716	22106.650	22155.919	21967.113	17381.830	17476.047	17701.256	17706.306	17519.710
21865.974									
195.000	224704.614	224466.998	225486.713	224549.187	250.000	223624.623	224035.822	225452.949	224024.754
224705.740	528.658	527.325	531.810	528.421	224413.928	525.217	525.470	531.505	527.274
531.270	446.787	447.302	451.544	447.823	530.130	445.487	446.530	451.061	447.018
449.081	80.380	80.023	80.254	80.507	449.038	80.730	79.941	80.444	80.257
81.189	5.544	5.599	5.627	5.496	81.100	5.518	5.533	5.607	5.571
5.544	425.280	425.896	423.901	424.649	423.112	424.966	426.353	424.178	424.877
423.280	105403.770	106624.512	106419.350	106287.547	81059.27	82120.158	81864.239	81664.686	81682.074
105403.770	21457.434	21453.920	21705.960	21567.571	17381.830	17476.047	17701.256	17706.306	17519.710
21457.434									
200.000	224193.334	224180.086	225499.484	224384.768	255.000	224152.004	224389.213	225390.447	224333.262
224780.489	526.795	526.795	531.858	528.421	224454.478	525.217	525.470	531.505	527.274
531.006	446.787	447.302	451.544	447.823	530.294	445.487	446.530	451.061	447.018
449.890	80.519	80.019	80.251	80.507	449.221	80.788	79.780	80.424	80.713
81.201	5.536	5.592	5.624	5.499	81.071	5.518	5.533	5.607	5.571
5.536	425.311	425.931	423.901	424.649	5.541	425.050	425.522	424.178	424.877
423.311	104393.565	104181.706	104218.447	104045.121	423.112	424.966	426.353	424.178	424.877
104393.565	21119.267	21305.549	21346.149	21148.215	78812.342	79887.449	79629.803	79392.051	79443.197
21049.434					16567.549	16665.425	16902.803	16895.754	16711.892
205.000	223291.513	223443.629	225399.246	223912.539	260.000	224790.096	224923.125	225328.832	224419.484
224802.459	526.157	526.458	531.754	527.280	224442.238	525.362	526.802	531.211	528.167
531.026	446.764	446.621	451.175	447.085	530.338	445.682	446.286	450.806	447.765
449.781	80.593	80.437	80.539	80.525	449.348	80.990	79.516	80.405	80.402
81.245	5.531	5.552	5.599	5.473	80.990	5.548	5.570	5.625	5.569
5.536	425.336	426.424	424.245	424.662	423.206	425.106	426.200	424.140	424.979
423.336	102163.737	101951.516	101960.324	101805.330	76563.795	77653.004	77392.319	77136.854	77202.040
101360.746	20714.531	20903.219	20941.215	20753.239	16160.400	16299.703	16503.451	16491.627	16307.451
20641.967									
210.000	223774.418	224000.057	225517.779	224165.320	265.000	224190.834	224473.662	225267.215	224430.166
224681.492	526.018	525.594	531.458	527.477	224626.008	526.572	526.927	531.064	528.032
530.803	446.384	446.498	451.002	447.177	530.598	445.946	447.334	450.678	447.522
449.490	80.634	79.096	80.556	80.290	449.385	80.726	79.593	80.386	80.511
81.153	5.541	5.645	5.599	5.470	81.213	5.533	5.525	5.606	5.559
5.541	425.286	426.437	424.258	424.662	423.345	425.050	425.522	424.178	424.877
423.286	99049.974	99033.019	99716.513	99645.802	74313.327	75418.214	75154.680	74881.399	74962.741
99049.974	20309.524	20503.562	20536.323	20349.989	15753.211	15854.384	16101.802	16047.496	15903.137
20234.210									
215.000	223803.010	223913.648	225436.313	224129.961	270.000	223337.064	223552.311	225205.600	223786.924
224673.176	526.145	526.777	531.767	527.566	224471.385	525.468	525.714	531.917	526.999
530.771	446.619	446.857	450.830	447.028	530.523	446.844	445.155	450.557	446.539
449.609	80.525	79.970	80.532	80.534	449.618	80.624	79.580	80.376	80.376
81.163	5.534	5.570	5.598	5.481	80.905	5.557	5.571	5.605	5.554
5.536	425.295	426.424	424.245	424.662	423.113	425.025	426.029	424.142	424.722
423.295	97708.225	97484.791	97466.810	97320.871	72064.542	73189.463	72825.363	72676.581	72726.455
96740.600	19804.529	20102.880	20131.547	19944.646	15446.042	15449.411	15701.948	15681.662	15499.134
19826.529									

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ENGINE PERFORMANCE PROGRAM (PA49)

275.000 224307.131 530.239 449.484 80.755 5.566 423.030 69814.944 14038.904	222987.236 525.321 445.118 80.707 5.550 424.478 70961.271 15044.499	223140.383 573.421 444.249 80.172 5.611 426.312 70697.749 15300.166	225143.952 530.170 450.222 80.148 5.606 424.184 73372.402 15279.822	223478.250 526.327 444.284 80.043 5.576 424.607 70491.120 15044.900	335.000 223113.907 525.019 448.594 80.421 5.578 422.888 45095.929 10469.661	222649.560 525.549 443.691 80.421 5.556 425.289 44495.189 10594.979	222511.047 522.449 442.409 80.060 5.524 425.884 46268.875 10893.646	187795.951 434.763 359.741 75.021 4.795 431.951 47683.141 10949.245	222958.199 525.011 444.898 80.113 5.553 424.680 45953.331 10866.428
285.000 224258.982 530.054 449.249 80.755 5.566 423.086 69765.130 14531.904	222687.520 524.690 444.377 80.313 5.533 424.417 68756.314 14639.935	222701.697 522.853 443.005 80.867 5.544 425.936 68469.904 14901.144	225059.040 530.563 450.237 80.326 5.605 424.189 68118.992 14875.079	223215.932 525.866 445.944 80.322 5.547 424.480 68256.703 14692.995	335.000 223618.881 523.711 448.362 80.418 5.575 422.912 42851.690 10053.157	222182.600 523.711 443.956 80.755 5.580 424.244 44273.329 10190.328	222550.729 521.199 443.363 77.837 5.586 426.997 44051.584 10483.024	187366.381 433.617 358.621 74.967 4.782 432.101 45886.244 10567.732	222784.066 524.557 445.220 74.937 5.413 424.719 43725.602 10242.170
285.000 224722.070 530.031 449.296 80.735 5.564 423.036 65117.244 14124.998	223180.059 525.439 445.175 80.102 5.543 426.750 66507.955 14235.069	223296.689 523.891 443.458 80.434 5.595 426.228 66243.969 14500.272	224455.754 530.075 450.290 80.290 5.602 424.215 65967.103 14472.497	223566.270 526.787 445.296 80.157 5.568 424.671 66073.055 14286.746	340.000 223465.592 528.397 448.028 80.370 5.575 422.914 40608.824 9645.566	222836.477 523.844 444.059 80.785 5.566 425.387 42052.042 9785.912	222668.818 523.007 442.623 80.184 5.523 425.747 41836.846 10041.639	187069.349 432.821 357.837 74.984 4.772 432.210 44093.196 10187.333	222990.627 525.083 444.970 80.113 5.554 424.683 41498.570 9837.705
290.000 224151.613 529.082 449.156 80.726 5.564 423.064 63744.851 13717.875	222908.351 524.345 444.724 80.319 5.528 425.117 64782.202 13810.093	222995.504 523.476 443.689 80.737 5.564 426.012 64018.680 14099.754	224642.945 529.511 449.261 80.251 5.598 424.246 63617.778 14049.044	223352.502 525.885 445.624 80.281 5.552 424.724 63789.883 13882.574	345.000 223371.127 529.076 447.650 80.426 5.568 422.980 38367.754 9237.956	221116.441 522.655 443.116 79.539 5.571 423.064 39832.316 9382.435	221129.689 518.571 439.781 78.780 5.582 426.819 39620.498 9402.447	186770.730 432.029 357.064 74.965 4.763 424.311 42304.453 9827.041	221872.082 523.101 443.516 79.585 5.572 424.158 39273.522 9434.184
295.000 224144.061 529.829 449.052 80.777 5.559 423.087 60821.221 13110.000	223120.061 524.416 445.052 80.311 5.530 425.464 62757.557 13425.137	223005.076 524.015 443.797 80.557 5.505 425.570 61794.954 13666.009	223445.713 529.476 449.387 80.089 5.574 424.456 61371.581 13666.009	223429.750 526.787 445.510 80.348 5.531 424.707 61547.913 13477.713	350.000 222955.904 526.821 446.434 80.387 5.554 423.095 36129.702 8830.354	223041.954 522.941 443.141 79.600 5.570 425.591 37613.729 8978.718	223012.332 523.520 443.777 79.790 5.561 425.984 37406.600 9282.447	186427.643 431.381 356.432 74.949 4.756 432.394 40519.234 9426.845	222990.627 524.427 444.902 79.926 5.541 424.224 37051.010 9030.506
300.000 22475.671 529.669 449.064 80.703 5.563 423.049 59533.153 12903.051	223765.499 524.557 444.791 80.266 5.535 426.180 59733.153 13020.977	223809.797 525.594 445.495 80.100 5.562 425.822 59474.364 13292.624	224000.563 529.264 449.850 80.414 5.582 425.174 59177.186 13265.535	223881.791 526.407 446.290 80.356 5.553 425.150 59327.098 13072.484	355.000 220544.943 529.724 446.435 80.088 5.562 423.535 33907.843 8423.560	220251.922 517.785 438.194 79.551 5.589 425.377 35405.993 8575.123	220184.328 516.890 437.253 79.655 5.584 425.979 35201.709 8892.295	186497.148 431.788 356.320 74.950 4.756 432.420 38735.592 9046.641	220327.729 518.466 438.698 79.778 5.496 424.964 36439.515 8626.993
305.000 223749.949 529.269 449.057 80.292 5.592 422.769 56326.472 12496.940	221828.686 524.818 445.107 80.713 5.484 422.677 57408.214 12617.703	221674.664 520.161 444.797 80.454 5.547 426.165 57353.369 12891.900	224014.838 487.294 449.877 77.417 5.294 426.877 57777.032 12700.098	222417.766 524.743 446.023 79.820 5.574 423.471 57904.018 12668.645	360.000 214796.422 505.804 426.437 79.367 5.373 424.663 31738.859 8019.367	214227.629 505.784 426.705 79.080 5.394 423.545 33240.074 8172.866	214354.172 501.924 426.018 77.906 5.443 427.065 33040.213 8483.324	186925.535 432.388 357.368 75.021 4.784 432.309 36449.616 8566.264	214459.406 504.504 438.698 79.778 5.404 425.094 32673.084 8225.186
310.000 223807.012 529.352 449.023 80.324 5.590 422.785 56076.527 12095.627	222476.123 523.700 444.058 80.402 5.545 425.408 55384.224 12217.680	222359.527 523.460 444.137 80.328 5.599 424.124 55116.031 12489.648	199311.232 444.728 348.185 76.343 5.599 425.877 55779.877 12479.859	223279.219 525.471 445.751 79.810 5.485 425.931 54866.594 12264.052	365.000 208953.260 490.581 411.893 78.687 5.235 425.931 29643.938 7618.988	208647.248 487.201 408.790 78.411 5.213 426.562 31153.714 7774.001	207186.387 481.890 407.520 76.469 5.324 426.080 30943.408 8092.707	187357.781 433.499 358.416 74.053 4.756 432.199 35194.344 8285.571	207662.297 487.257 409.401 77.856 5.591 425.191 30581.687 7824.087
315.000 223799.744 529.302 448.932 80.370 5.586 422.821 51832.904 11682.740	222679.041 523.432 443.646 79.786 5.560 425.325 53161.424 11808.318	222532.492 522.401 442.567 79.834 5.544 425.980 52918.527 12094.744	194505.229 442.251 376.494 75.787 5.569 430.049 53171.985 12094.121	222987.090 525.045 445.048 79.987 5.563 424.709 52637.627 11859.922	370.000 203882.902 477.465 399.453 78.012 5.120 427.011 27616.746 7222.102	201756.621 473.964 396.420 77.544 5.117 425.679 29137.160 7378.659	202215.986 471.460 394.204 75.254 5.265 428.914 28933.061 7708.982	147781.814 434.589 359.445 75.145 4.783 432.090 33161.974 7904.569	202618.502 474.296 397.359 74.937 5.166 427.202 28567.088 7436.581
320.000 223733.518 529.147 448.800 80.347 5.586 422.819 49586.767 11275.419	221152.275 524.114 444.200 79.914 5.559 421.954 50918.761 11403.980	221107.427 518.595 440.250 75.346 5.619 426.744 50701.432 11686.939	190862.434 442.780 367.440 75.740 4.877 431.055 51311.544 11710.706	222044.404 523.942 444.416 79.536 5.488 423.539 50604.752 11455.466	375.000 199539.645 466.212 388.762 77.451 5.019 426.002 25644.374 6828.083	197577.709 462.905 386.168 76.739 5.032 426.821 27187.339 6988.094	198050.283 460.991 386.537 74.454 5.192 429.619 26874.977 7331.081	188204.291 435.675 360.469 75.206 4.793 431.883 31569.333 7523.263	198389.211 463.370 387.155 76.214 5.591 425.194 26599.966 7049.087
325.000 223649.332 528.924 448.582 80.342 5.583 422.838 47341.139 10868.132	222324.447 523.571 443.871 79.740 5.566 424.631 48715.893 10999.446	222383.717 521.564 442.506 79.059 5.597 426.379 48484.441 11285.570	188731.518 437.151 382.048 75.102 4.821 431.667 49489.291 11329.126	222785.830 524.684 444.973 79.713 5.582 424.614 49180.447 11051.049	380.000 195873.502 456.622 378.559 77.063 4.925 428.942 23721.483 6436.566	194847.176 455.020 378.638 76.383 4.957 428.216 25264.468 6600.275	195372.614 454.511 380.354 74.154 5.129 429.852 25053.188 6956.299	148163.521 435.566 360.362 74.204 4.792 431.998 29754.468 7141.802	195364.561 455.584 379.518 75.867 5.004 429.010 24679.712 6664.390

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133437.008	127155.877	192497.832	184111.234	192884.932	425.000	183880.797	186214.430	187198.247	188877.725	187264.488
450.276	448.360	448.101	435.434	448.913	437.181	437.181	437.789	432.774	432.078	434.568
373.572	372.585	374.435	374.230	373.590	361.054	361.054	362.393	362.393	357.063	360.930
76.704	75.771	73.466	75.195	75.314	70.127	70.127	76.446	70.362	75.015	73.631
4.870	4.917	4.099	4.791	4.962	4.743	4.743	4.827	5.152	4.740	4.907
429.530	429.721	430.478	432.009	429.676	433.899	433.899	429.274	432.594	432.147	430.922
21830.229	23381.452	23164.428	27553.247	22794.079	7247.378	7247.378	8007.875	8603.271	13605.157	8182.575
6046.937	6214.671	6584.483	6769.178	6282.030	2955.903	2955.903	3177.679	3682.033	3713.433	3271.871
190.000					430.000	430.000				
191767.984	190967.783	191719.027	197734.186	191483.262	188974.008	188974.008	197165.399	188025.748	186922.674	188044.379
466.997	445.119	444.781	436.461	445.313	438.775	438.775	436.244	435.014	432.384	434.678
369.551	369.501	372.248	379.440	377.440	362.624	362.624	361.719	364.207	357.161	362.808
76.495	75.413	72.913	75.145	74.872	76.127	76.127	76.575	70.812	75.023	73.830
4.832	4.886	5.134	4.782	4.951	4.762	4.762	4.854	5.143	4.763	4.909
429.937	429.014	431.041	432.109	429.090	430.685	430.685	429.943	432.229	432.307	430.676
19976.635	21520.314	21293.098	24152.426	20930.186	5436.243	5436.243	7001.913	6455.754	11817.346	6371.103
5658.574	5831.374	6217.191	6379.102	5902.413	2570.303	2570.303	2800.124	3321.758	3332.002	2897.304
395.000					435.000	435.000				
190594.368	190054.609	190937.517	187546.732	190528.525	189126.496	189126.496	197956.660	188762.295	187027.413	189615.148
447.944	442.498	442.386	433.704	444.673	439.220	439.220	437.678	436.992	432.675	437.943
366.584	367.317	370.465	358.454	368.207	363.093	363.093	363.749	365.652	357.696	361.916
76.164	75.175	71.720	75.114	74.464	76.127	76.127	76.575	70.812	75.023	74.027
4.800	4.978	5.188	4.777	4.949	4.770	4.770	4.861	5.130	4.769	4.907
430.273	429.136	431.609	432.157	433.405	430.685	430.685	429.943	432.071	432.259	430.685
14130.295	19671.707	19437.760	24355.985	19078.921	3619.000	3619.000	5187.680	4884.531	10028.056	4551.737
5271.214	5448.957	5880.333	5998.047	5521.516	2184.618	2184.618	2401.853	2958.685	2952.323	2521.719
400.000					440.000	440.000				
190091.379	188482.029	189295.658	187436.187	189287.188	189491.125	189491.125	197893.061	188574.053	187449.299	188457.744
441.523	439.874	438.273	433.851	439.090	440.194	440.194	438.755	436.916	433.786	438.027
365.508	365.019	368.922	354.742	365.749	364.045	364.045	363.499	365.064	358.730	366.203
76.115	74.856	71.281	75.109	74.151	76.127	76.127	76.575	71.751	75.056	74.217
4.747	4.876	5.168	4.776	4.937	4.781	4.781	4.863	5.088	4.780	4.917
437.421	428.490	431.982	437.157	439.708	430.472	430.472	429.734	431.701	432.124	430.372
16370.966	17813.706	17590.943	22545.261	17243.514	1199.606	1199.606	3370.114	3018.748	8235.736	2729.489
6846.350	5088.490	5485.286	5617.053	5144.375	1794.977	1794.977	2043.416	2595.897	2571.782	2144.098
405.000					445.000	445.000				
189126.913	187564.855	188484.909	187390.531	188604.189	189791.271	189791.271	198868.104	189528.144	187380.736	189395.840
439.299	437.150	436.743	433.403	437.368	443.996	443.996	439.768	439.234	433.678	440.001
3635.76	362.517	365.206	358.508	363.690	364.887	364.887	364.917	367.107	358.508	365.046
76.222	76.419	70.837	74.009	73.050	76.166	76.166	74.952	72.748	75.030	74.355
4.763	4.864	5.156	4.774	4.921	4.790	4.790	4.875	5.155	4.779	4.921
437.676	428.815	432.241	437.191	437.386	430.370	430.370	429.472	431.493	432.123	430.445
14476.333	16020.417	15749.779	20745.274	15619.510	-24.257	-24.257	1047.513	1185.922	6440.672	903.000
4407.988	4689.741	5124.351	5234.100	4771.526	1413.143	1413.143	1866.742	2233.235	2191.139	1771.373
417.000					446.000	446.000				
189581.376	186443.446	187388.569	187223.463	187464.355	189001.957	189001.957	198878.236	189656.129	187363.366	189678.773
437.403	436.763	433.219	431.140	435.215	441.244	441.244	440.705	439.121	433.587	440.236
361.479	361.163	362.411	354.074	361.417	365.110	365.110	365.532	367.762	358.563	368.900
76.164	76.071	70.608	75.072	73.797	76.174	76.174	76.767	71.382	74.024	74.106
4.765	4.868	5.156	4.777	4.903	4.795	4.795	4.880	5.152	4.779	4.945
439.482	428.890	432.503	437.238	439.742	430.334	430.334	428.981	431.896	432.124	430.464
12665.475	14215.027	13936.553	18072.045	13604.318	-389.517	-389.517	1181.996	1181.677	6081.677	534.864
4117.117	4310.554	4742.245	4955.285	4394.085	1335.973	1335.973	1598.888	2160.735	2115.027	1695.199
415.000					447.000	447.000				
189378.334	186993.201	187793.959	187967.209	187479.466	189012.408	189012.408	198978.135	189748.135	187345.959	189884.563
436.986	436.148	434.425	432.495	435.423	441.244	441.244	440.000	439.000	433.566	441.001
360.951	360.232	363.137	357.647	361.417	365.093	365.093	367.107	368.664	358.528	366.906
76.744	76.616	71.288	75.049	73.983	76.105	76.105	76.861	71.360	75.014	74.126
4.767	4.828	5.096	4.766	4.889	4.791	4.791	4.880	5.168	4.779	4.955
430.554	429.817	432.075	432.285	430.914	430.334	430.334	428.981	431.896	432.124	430.464
10457.444	12464.258	12119.036	17181.718	11796.566	-330.000	-330.000	1181.996	1181.677	6081.677	534.864
3726.560	3932.537	4431.124	4476.914	4071.067	1259.573	1259.573	1513.100	2098.397	2038.921	1627.099
420.000					448.000	448.000				
189011.854	186144.148	187062.441	186471.037	187085.190	190030.888	190030.888	192010.758	192818.018	187327.230	191619.820
436.396	433.318	432.533	432.495	436.082	441.554	441.554	440.912	439.121	433.587	441.394
360.350	358.424	361.909	357.216	360.361	365.299	365.299	367.321	368.664	358.508	368.917
76.086	74.466	70.625	76.074	74.093	76.255	76.255	75.191	72.000	75.012	74.482
4.739	4.817	5.124	4.761	4.903	4.790	4.790	4.880	5.168	4.779	4.952
430.763	429.555	432.481	432.531	431.993	430.334	430.334	428.981	431.896	432.124	430.464
9142.581	10675.200	10364.457	15192.148	9087.787	-1148.556	-1148.556	1181.996	1181.677	6081.677	534.864
3341.215	3554.044	4042.066	4073.935	3644.074	1175.575	1175.575	1431.218	2010.161	1946.301	1530.018

AP 2

ABBREVIATIONS

TABLE AP 2-1 (Sheet 1 of 2)
ABBREVIATIONS

ITEM	TERM	ITEM	TERM
ac	Alternating current	He	Helium
Act	Actuator	hr	Hour
APS	Auxiliary Propulsion System	Hyd	Hydraulic
Attch	Attach	in.	Inch
Btu	British thermal unit	IP&CL	Instrumentation Program and Component List
Cfm	Cubic feet per minute	IU	Instrumentation unit
Contr	Control	K	Kilo = 1,000 or 10^3
cps	Cycles per second	kc	Kilocycle
DAC	Douglas Aircraft Company, Inc.	KSC	Kennedy Space Center
db	Decibel	lbf	Pounds force
dc	Direct current	lbm	Pounds mass
DDAS	Digital Data Acquisition System	LH2	Liquid hydrogen
Disch	Discharge	Loc	Location
DPF	Differential Pressure Feedback	LOX	Liquid oxygen
EBW	Exploding Bridgewire	ms	Millisecond
ECC	Engine Cutoff Command	MSFC	Marshall Space Flight Center
E/I	External/Internal	NASA	National Aeronautics and Space Administration
EMI	Electromagnetic Interference	NPSH	Net positive suction head
EMR	Engine mixture ratio	PAM	Pulse amplitude modulation
ESC	Engine Start Command	PCM	Pulse code modulation
FLT	Flight	pf	Picofarad
ft	Feet	Posit	Position
FM	Frequency modulation	pps	Pulses per second
FTC	Florida Test Center	Press	Pressure
Fwd	Forward	psia	Pounds per square inch, absolute
GG	Gas generator	psid	Pounds per square inch, differential
GH2	Gaseous hydrogen	psig	Pounds per square inch, gauge
GN2	Gaseous nitrogen	Pt	Point
gpm	Gallons per minute		
GSE	Ground support equipment		

TABLE AP 2-1 (Sheet 2 of 2)
ABBREVIATIONS

ITEM	TERM	ITEM	TERM
PU	Propellant utilization	sw	Switch
Pwr	Power	Syst	System
R	Rankine	TAN	Tangential
RAD	Radial	Temp	Temperature
Refl	Reflected	T/M	Telemetry
Reg	Regulator	TP&E	Test Planning and Evaluation
RF	Radio frequency	TRW	Thompson-Ramo-Wooldridge
RMR	Reference mixture ratio	Vac	Volts alternating current (100 vac)
RSS	Root sum square	V	Volts
SCI	Standard cubic inch	Vib	Vibration
scim	Standard cubic inch per minute	vdc	volts direct current
scfm	Standard cubic foot per minute	W	Watts
sec	Second		
STC	Sacramento Test Center		

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KBBO Branch Chief - Structures
KCOO Chief Engineer - Propulsion
KCBO Branch Chief - Propulsion Analysis
KCBC Section Chief - Propulsion Performance & TP&E
KCBC Propulsion Performance and TP&E - Analysis
KCDO Branch Chief - Propulsion Test
KCDE Propulsion Test
DKOO Chief Engineer - Electronics
KDBA Section Chief - Test Planning & Evaluation
KDCO Branch Chief - Electronics S-IVB Stage Design
KDCA Section Chief - Networks & Subsystem Design
KDFO Branch Chief - Data Systems
KECO Branch Chief - Computing Engineering
KFOO Chief Engineer - Vehicle Checkout Laboratory
KKOO Chief Project Engineer - Saturn Development
KKBO Project Engineer - Test
KKBO Deputy Project Engineer - Test
KKBA Assistant Project Engineer - TP&E
KKBA Supervisor - S-IVB Static Test

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KABA Strength
KABB Weight Control

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